INSTRUCTION MANUAL

Serial Number 28724

TYPE
453/R453
OSCILLOSCOPE
ABOVE SN 20,000

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867

WARRANTY

All Tektronix instruments are warranted against defective materials and workmanship for one year. Tektronix transformers, manufactured in our own plant, are warranted for the life of the instrument.

Any questions with respect to the warranty mentioned above should be taken up with your Tektronix Field Engineer.

Tektronix repair and replacement-part service is geared directly to the field, therefore all requests for repairs and replacement parts should be directed to the Tektronix Field Office or representative in your area. This procedure will assure you the fastest possible service. Please include the instrument Type and Serial or Model Number with all requests for parts or service.

Specifications and price change privileges reserved.

SECTION 1
CHARACTERISTICS

Change information, if any, affecting this section is found at the rear of the manual.

Introduction

The Tektronix Type 453 Oscilloscope is a transistorized portable oscilloscope designed to operate in a wide range of environmental conditions. The light weight of the Type 453 allows it to be easily transported, while providing the performance necessary for accurate high-frequency measurements. The dual-channel DC-to-50 MHz vertical system provides calibrated deflection factors from 5 millivolts to 10 volts/division. Channels 1 and 2 can be cascaded using an external cable to provide a one millivolt minimum deflection factor (both VOLTS/DIV switches set to 5 mV).

The trigger circuits provide stable triggering over the full range of vertical frequency response. Separate trigger controls are provided to select the desired triggering for the A and B sweeps. One of three sweep modes can be selected for the A sweep; automatic, normal or single sweep. The horizontal sweep provides a maximum sweep rate of 0.1 microsecond/division (10 nanoseconds/division using 10× magnifier) along with a delayed sweep feature for accurate relative-time measurements. Accurate X-Y measurements can be made with Channel 2 providing the vertical deflection, and Channel 1 providing the horizontal deflection. (TRIGGER switch set to CH 1 ONLY, HORIZ DISPLAY switch set to EXT HORIZ). The regulated DC power supplies maintain constant output over a wide variation of line voltages and frequencies. Total power consumption of the instrument is approximately 90 watts.

Information given in this instruction manual applies to the Type R453 also unless otherwise noted. The Type R453 is electrically identical to the Type 453 but is mechanically adapted for mounting in a standard 19-inch rack. Rackmounting instructions, a mechanical parts list and a dimensional drawing for the Type R453 are provided in Section 10 of this manual.

The electrical characteristics which follow are divided into two categories. Characteristics listed in the Performance Requirement column are checked in the Performance Check and Calibration sections of this manual. Items listed in the Operational Information column are provided for reference use and do not directly reflect the measurement capabilities of this instrument. The Performance Check procedure given in Section 5 of this manual provides a convenient method of checking the items listed in the Performance Requirement column. The following electrical characteristics apply over a calibration interval of 1000 hours at an ambient temperature range of —15°C to +55°C, except as otherwise indicated. Warm-up time for given accuracy is 20 minutes.

ELECTRICAL CHARACTERISTICS

VERTICAL DEFLECTION SYSTEM

Characteristic	Performance Requirement	Operational Information
Deflection Factor	5 millivolts/division to 10 volts/division in 11 calibrated steps for each channel. One millivolt/division when Channel 1 and 2 are cascaded.	Steps in 1-2-5 sequence
Deflection Accuracy	Within ±3% of indicated deflection with VARIABLE control set to CAL. Cascaded deflection factor uncalibrated.	With gain correct at 20 mV
Variable Deflection Factor	Uncalibrated deflection factor at least 2.5 times the VOLTS/DIV switch indication. This provides a maximum uncalibrated deflection factor of 25 volts/division in the 10 volts position.	
Bandwidth at Upper —3 dB point (with or without P6010 Probe) 20 mV to 10 VOLTS/DIV	DC to 50 MHz or greater	Driven from 25-ohm source
10 mV/DIV	DC to 45 MHz or greater	
5 mV/DIV	DC to 40 MHz or greater	
Channels 1and 2 cascaded	DC to 25 MHz or greater	Measured at one millivolt/division
Risetime (calculated). With or without P6010 Probe. 20 mV to 10 VOLTS/DIV	Less than 7 nanoseconds	Risetime calculated from bandwidth measurement using the formula: $t_r = \frac{350}{BW}$ Where: t_r = Risetime in nanoseconds. BW = Bandwidth in megahertz.
10 mV/DIV	Less than 7.8 nanoseconds	
5 mV/DIV	Less than 8.75 nanoseconds	
Channels 1 and 2 cascaded	Less than 14 nanoseconds	

VERTICAL *(cont)*

Characteristic	Performance Requirement	Operational Information	
Input RC Characteristics		Typically 1 megohm (±2%), paralleled by 20 pF (±3%)	
Maximum Input Voltage		600 volts DC + peak AC (one kilohertz or less). Peak-to-peak AC not to exceed 600 volts.	
Input Coupling Modes	AC or DC, selected by front-panel switch		
AC Low-Frequency Response (lower —3 dB point)			
Without probe		Typically 1.6 Hz, Input Coupling switch set to AC	
With P6010 Probe		Typically 0.16 Hz	
Trace Shift Due to Input Gate Current (at 25°C)	Negligible		
Vertical Display Modes	Channel 1 only Channel 2 only Dual-trace, alternate between channels Dual-trace, chopped between channels Added algebraically		
Chopped Repetition Rate	Approximately one-microsecond segments from each channel displayed at repetition rate of 500 kHz, ±20%.		
Attenuator Isolation	Greater than 10,000:1, DC to 20 MHz		
Common Mode Rejection Ratio	Greater than 20:1 at 20 MHz for common-mode signals less than eight times VOLTS/DIV switch setting.	With optimum GAIN adjustment at low frequency	
Linear Dynamic Range Useful for Common-Mode Rejection in ADD Mode		Less than 10% incremental signal distortion for instantaneous input voltage of —10 or +10 times VOLTS/DIV switch setting	
Polarity Inversion	Signal on Channel 2 can be inverted		
Signal Delay Line		Approximately 140 nanoseconds	
Low-Frequency Vertical Linearity	Less than 0.15 division compression or expansion of two division signal when positioned to vertical extremes of display area	Includes CRT linearity. Measured with one-kilohertz square wave.	
Trace Drift (after 20 minute warm up)		Time	Temperature
20 mV to 10 VOLTS/DIV		Typically less than 0.03 division/hour	Typically less than 0.0075 division/degree C
10 mV/DIV		Typically less than 0.05 division/hour	Typically less than 0.0125 division/degree C
5 mV/DIV		Typically less than 0.08 division/hour	Typically less than 0.02 division / degree C

TRIGGERING (A AND B SWEEP)

Source	Internal from displayed channel or from Channel 1 only Internal from AC power source External External divide by 10	
Coupling	AC AC low-frequency reject AC high-frequency reject DC	
Polarity	Sweep can be triggered from positive-going or negative-going portion of trigger signal	

TRIGGERING *(cont)*

Characteristic	Performance Requirement	Operational Information
Internal Trigger Sensitivity AC	0.2 division of deflection, minimum, 30 Hz to 10 MHz; increasing to 1 division at 50 MHz	Typical —3 dB point, 16 Hz
LF REJ	0.2 division of deflection, minimum, 30 Hz to 10 0.2 division of deflection, minimum, 30 kHz to 10	Typical —3 dB point, 16 kHz
HF REJ	0.2 division of deflection, minimum, 30 Hz to 50 kHz	Typical —3 dB points, 16 Hz and 100 kHz
DC	0.2 division of deflection, minimum, DC to 10 MHz; increasing to 1 division at 50 MHz	
External Trigger Sensitivity AC	50 millivolts, minimum, 30 Hz to 10 MHz; increasing to 200 millivolts at 50 MHz	Typical —3 dB point, 16 Hz
LF REJ	50 millivolts, minimum, 30 kHz to 10 MHz; increasing to 200 millivolts at 50 MHz	Typical —3 dB point, 16 kHz
HF REJ	50 millivolts, minimum, 30 Hz to 50 kHz	Typical —3 dB points, 16 Hz and 100 kHz
DC	50 millivolts, minimum, DC to 10 MHz; increasing to 200 millivolts at 50 MHz	
Auto Triggering (A sweep only)	Stable display presented with signal amplitudes given under Internal and External Trigger Sensitivity above 20 Hz. Presents a free-running sweep for lower frequencies or in absence of trigger signal.	
Single Sweep (A sweep only)	A Sweep Generator produces only one sweep when triggered. Further sweeps are locked out until RESET button is pressed. Trigger sensitivity same as given above.	
Display Jitter	Less than 1 nanosecond at 10 nanoseconds/division sweep rate (MAG switch set to ×10)	
Maximum Input Voltage		600 volts DC + peak AC (one kilohertz or less). Peak-to-peak AC not to exceed 600 volts.
External Trigger Input RC Characteristics (approximate)		1 Megohm paralleled by 20 pF, except in LF REJ
LEVEL Control Range	At least ±2 volts, SOURCE switch in EXT position. At least ±20 volts, SOURCE switch in EXT ÷10 position	

HORIZONTAL DEFLECTION SYSTEM

A and B Sweep Generator

Sweep Rates A sweep	0.1 microsecond/division to 5 seconds/division in 24 calibrated steps		A sweep is main and delaying sweep
B sweep	0.1 microsecond/division to 0.5 second/division in 21 calibrated steps		B sweep is delayed sweep
Sweep Accuracy—A and B Sweep	0°C to +40°C	−15°C to +55°C	
5 s to 0.1 s/DIV	Within ±3% of indicated sweep rate	Within ±5% of indicated sweep rate	A VARIABLE and B TIME/DIV VARIABLE controls set to CAL
50 ms to 0.1 μs/DIV	Within ±3% of indicated sweep rate	Within ±4% of indicated sweep rate	
Variable Sweep Rate	Uncalibrated sweep rate to at least 2.5 times the TIME/DIV indication, or a maximum of at least 12.5 seconds/division in the 5 s position (B sweep, maximum of 1.25 seconds/division in the .5 s position.		

A and B Sweep Generator

Characteristic	Performance Requirement	Operational Information
Sweep Length A sweep	Variable from less than 4 divisions to 11.0, ±0.5 division	A TIME/DIV switch set to 1 ms
B sweep	11.0 divisions, ±0.5 division	B TIME/DIV switch set to 1 ms
Sweep Hold-off—A sweep 5 s to 10 μs/DIV	Less than one times the A TIME/DIV switch setting	
5 μs to 0.1 μs/DIV	Less than 2.5 microseconds	

Sweep Magnifier

Characteristic	Performance Requirement	Operational Information
Sweep Magnification	Each sweep rate can be increased 10 times the indicated sweep rate by horizontally expanding the center division of display	Extends fastest sweep rate to 10 nanoseconds/division
Magnified Sweep Accuracy	1% tolerance added to specified sweep accuracy	
Magnified Sweep Linearity	±1.5% for any eight division portion of the total magnified sweep length (excluding first and last 60 nanoseconds of magnified sweep)	
Normal/Magnified Registration	±0.2 division, or less, trace shift at graticule center when switching MAG switch from ×10 to OFF	

Sweep Delay

Characteristic	Performance Requirement		Operational Information
Calibrated Delay Time Range	Continuous from 50 seconds to 1 microsecond		A VARIABLE control set to CAL for indicated delay
DELAY-TIME MULTIPLIER Dial Range	0.20 to 10.20		
Delay Time Accuracy	0°C to +40°C	−15°C to +55°C	Includes incremental multiplier linearity
5 s to 0.1 s/DIV	Within ±2.5% of indicated delay	Within ±3.5% of indicated delay	
50 ms to 1 μs/DIV	Within ±1.5% of indicated delay	Within ±2% of indicated delay	
Incremental Multiplier Linearity	±0.2%	±0.3%	
Delay Time Jitter	Less than 1 part in 20,000 of 10 times A TIME/DIV switch setting		Equal to 0.5 division, or less, with the A TIME/DIV switch set to 1 ms and the B TIME/DIV switch set to 1 μs.

External Horizontal Amplifier

Characteristic	Performance Requirement		Operational Information
Input to Channel 1 (TRIGGER switch in CH 1 ONLY) Deflection factor	5 millivolts/division to 10 volts/division in 11 calibrated steps		Steps in 1-2-5 sequence. Channel 1 VARIABLE control does not affect horizontal deflection
Accuracy	0°C to +40°C	−15°V to +55°C	
	Within ±5% of indicated deflection	Within ±8% of indicated deflection	With external horizontal gain correct at 20 mV
X Bandwidth at Upper −3 dB Point	5 MHz or greater		
Input RC characteristics			Typically 1 megohm (±2%), paralleled by 20 pF (±3%)
Phase difference between X and Y amplifiers at 50 kHz	Less than 3°		
Input to EXT HORIZ Connector Deflection factor	B SOURCE switch in EXT; 270 millivolts/division, ±15%. B SOURCE switch in EXT ÷ 10; 2.7 volts/division, ±20%		

External Horizontal Amplifier *(cont)*

Characteristic	Performance Requirement	Operational Information
X Bandwidth at Upper —3 db point	5 MHz or greater	
Input RC characteristics (approximate)		1 megohm, paralleled by 20 pF
Phase difference between X and Y amplifiers at 50 kHz		Less than 3°

CALIBRATOR

Waveshape	Square wave		
Polarity	Positive going with baseline at zero volts		
Output Voltage	0.1 volt or 1 volt, peak to peak		Selected by CALIBRATOR switch on side panel
Output Current	5-milliamperes through PROBE LOOP on side panel		
Repetition Rate	1 kHz		
	0°C to +40°C	—15°C to +55°C	
Voltage Accuracy	±1%	±1.5%	
Current Accuracy	±1%	±1.5%	
Repetition Rate Accuracy	±0.5%	±1%	
Risetime	Less than 1 microsecond		
Duty Cycle	49% to 51%		
Output Resistance			Approximately 200 ohms in 1 V position. Approximately 20 ohms in .1 V position.

Z AXIS INPUT

Sensitivity	5 volt peak-to-peak signal produces noticeable modulation	
Usable Frequency Range	DC to greater than 50 MHz	
Input Resistance at DC		Approximately 47 kilohms
Input Coupling	DC coupled	
Polarity of Operation		Positive-going input signal decreases trace intensity Negative-going signal increases trace intensity
Maximum Input Voltage		200 volts combined DC and peak AC

OUTPUT SIGNALS

A and B Gate		
Waveshape	Rectangular pulse	
Amplitude	12 volts peak, ±10%	
Polarity	Positive-going with baseline at about —0.7 volts.	
Duration	Same duration as the respective sweep	A GATE duration variable between about 4 and 11 times the A TIME/DIV switch setting with the A SWEEP LENGTH control.
Output resistance		Approximately 1.5 kilohms
Vertical Signal Out (CH 1 only)		
Output voltage	25 millivolts, or greater/division of CRT display into 1 megohm load.	
Bandwidth	DC to 25 MHz or greater when cascaded with Channel 2 or into 50-ohm load.	
Output coupling	DC coupled	
Output resistance		Approximately 50 ohms

POWER SUPPLY

Characteristic	Performance Requirement	Operational Information
Line Voltage	115 volts nominal or 230 volts nominal	
Voltage Ranges (AC, RMS) 115-volts nominal	90 to 110 volts 104 to 126 volts 112 to 136 volts	Line voltage and range selected by Line Voltage Selector assembly on rear panel. Voltage ranges apply for waveform distortion which does not reduce the peak line voltage more than 5% below the true sine-wave peak value.
230-volts nominal	180 to 220 volts 208 to 252 volts 224 to 272 volts	
Line Frequency	48 to 440 Hz	
Maximum Power Consumption at 115 Volts, 60 Hz		92 watts (105 volt-amperes)

CATHODE-RAY TUBE (CRT)

Tube Type		Tektronix T4530-31-1 rectangular
Phosphor		P31 standard. Others available on special order.
Accelerating Potential		Approximately 10 kV total (cathode potential —1.95 kV).
Graticule Type	Internal	
Area	Six divisions vertical by 10 divisions horizontal. Each division equals 0.8 centimeter.	
Illumination		Variable edge lighting
Unblanking		Bias-type, DC coupled to CRT grid.
Raster Distortion	0.1 division or less total	Adjustable with Geometry and Y Axis Align adjustments.
Trace Finder	Limits display within graticule area when pressed.	

ENVIRONMENTAL CHARACTERISTICS

The following environmental test limits apply when tested in accordance with the recommended test procedure. This instrument will meet the electrical characteristics given in this section following environmental test. Complete details on environmental test procedures, including failure criteria, etc., may be obtained from Tektronix, Inc. Contact your local Tektronix Field Office or representative.

Characteristic	Performance Requirement	Supplemental Information
Temperature Operating	—15°C to +55°C	Fan at rear circulates air throughout instrument. Automatic resetting thermal cutout protects instrument from overheating.
Non-operating	—55° to +75°C	
Altitude Operating	15,000 feet maximum	Derate maximum operating temperature by 1°C/1000 feet change in altitude above 5000 feet.
Non-operating	50,000 feet maximum	
Humidity Non-operating	Five cycles (120 hours) of Mil-Std-202C, Method 106B	Exclude freezing and vibration
Vibration Operating and non-operating	15 minutes along each of the three major axes at a total displacement of 0.025-inch peak to peak (4 g at 55 c/s) with frequency varied from 10-55-10 c/s in one-minute cycles. Hold at 55 c/s for three minutes on each axis.	Instrument secured to vibration platform during test. Total vibration time, about 55 minutes.
Shock Operating and non-operating	Two shocks of 30 g, one-half sine, 11 millisecond duration each direction along each major axis.	Guillotine-type shocks. Total of 12 shocks

ENVIRONMENTAL CHARACTERISTICS *(cont)*

Characteristic	Performance Requirement	Operational Information
Transportation	Meets National Safe Transit type of test when packaged as shipped from Tektronix, Inc.	
Package vibration	One hour vibration slightly in excess of 1 g.	Package should just leave vibration surface
Package drop		
Type 453	30-inch drop on any corner, edge or flat surface.	
Type R453	18-inch drop on any corner, edge or flat surface.	

MECHANICAL CHARACTERISTICS

Characteristic	Information
Construction	
Chassis	Aluminum alloy
Panel	Aluminum alloy with anodized finish
Cabinet	Blue vinyl-coated aluminum
Circuit boards	Glass-epoxy laminate
Overall Dimensions, Type 453 (measured at maximum points)	
Height	$7\frac{1}{4}$ inches
Width	$12\frac{1}{2}$ inches
Length	$20\frac{1}{2}$ inches (includes front cover); $22\frac{3}{8}$ inches with handle positioned for carrying.
Overall Dimensions, Type R453 (measured at maximum points)	
Height	7 inches
Width	19 inches
Length	$17\frac{3}{4}$ inches behind front panel; $19\frac{9}{16}$ inches overall
Connectors	
Z AXIS INPUT	Binding post
All other connectors	BNC
Net Weight	
Type 453 (includes front cover without accessories)	Approximately 29 pounds.
Type R453 (without accessories)	Approximately 32 pounds.

STANDARD ACCESSORIES

Standard accessories supplied with the Type 453 and R453 are listed on the last pullout page of the Mechanical Parts List illustrations. For optional accessories available for use with this instrument, see the current Tektronix, Inc. catalog.

NOTES

SECTION 2
OPERATING INSTRUCTIONS

Change information, if any, affecting this section is found at the rear of the manual.

General

To effectively use the Type 453, the operation and capabilities of the instrument must be known. This section describes the operation of the front-, side- and rear-panel controls and connectors, gives first time and general operating information and lists some basic applications for this instrument.

Front Cover and Handle

The front cover furnished with the Type 453 provides a dust-tight seal around the front panel. Use the cover to protect the front panel when storing or transporting the instrument. The cover also provides storage space for probes and other accessories (see Fig. 2-1).

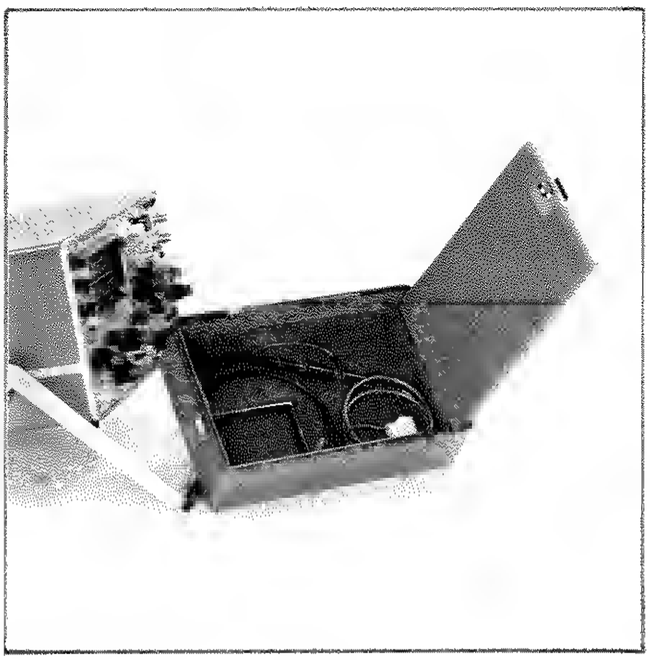


Fig. 2-1. Accessory storage provided in front cover.

The handle of the Type 453 can be positioned for carrying or as a tilt-stand for the instrument. To position the handle, press in at both pivot points (see Fig. 2-2) and turn the handle to the desired position. Several positions are provided for convenient carrying or viewing. The instrument may also be set on the rear-panel feet for operation or storage.

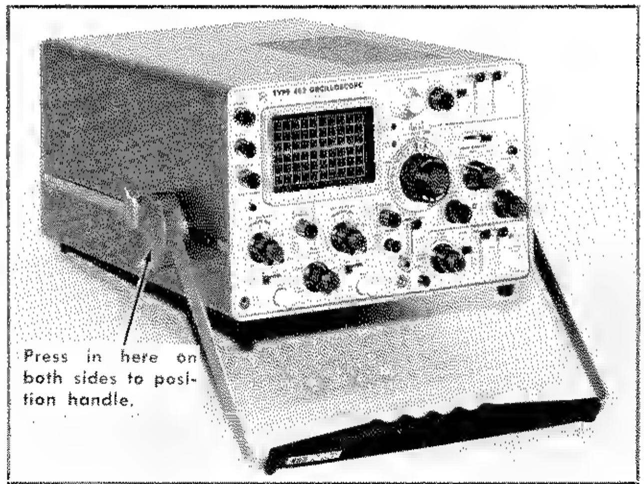


Fig. 2-2. Handle positioned to provide a stand for the instrument.

Operating Voltage

The Type 453 can be operated from either a 115-volt or a 230-volt nominal line-voltage source. The Line Voltage Selector assembly on the rear panel converts the instrument from one operating range to the other. In addition, this assembly changes the primary connections of the power transformer to allow selection of one of three regulating ranges. The assembly also includes the two line fuses. When the instrument is converted from 115-volt to 230-volt nominal operation, or vice versa, the assembly connects or disconnects one of the fuses to provide the correct protection for the instrument. Use the following procedure to convert this instrument between nominal line voltages or regulating ranges.

1. Disconnect the instrument from the power source.

2. Loosen the two captive screws which hold the cover onto the voltage selector assembly; then pull to remove the cover.

3. To convert from 115-volts nominal to 230-volts nominal line voltage, pull out the Voltage Selector switch bar (see Fig. 2-3); turn it around 180° and plug it back into the remaining holes. Change the line-cord power plug to match the power-source receptacle or use a 115- to 230-volt adapter.

4. To change regulating ranges, pull out the Range Selector switch bar (see Fig. 2-3); slide it to the desired position and plug it back in. Select a range which is centered about the average line voltage to which the instrument is to be connected (see Table 2-1).

5. Re-install the cover and tighten the two captive screws.

6. Before applying power to the instrument, check that the indicating tabs on the switch bars are protruding through the correct holes for the desired nominal line voltage and regulating range.

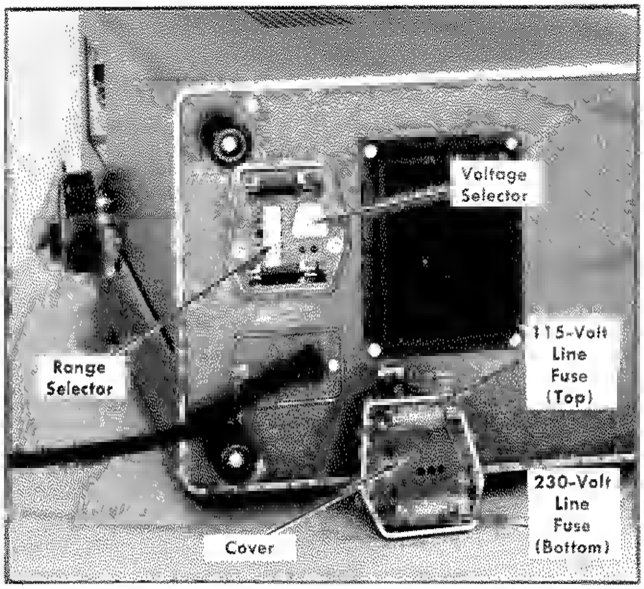


Fig. 2-3. Line Voltage Selector assembly on the rear panel (shown with cover removed).

CAUTION

The Type 453 should not be operated with the Voltage Selector or Range Selector switches in the wrong positions for the line voltage applied. Operation of the instrument with the switches in the wrong positions may either provide incorrect operation or damage the instrument.

TABLE 2-1

Regulating Ranges

Range Selector Switch Position	Regulating Range	
	115-Volts Nominal	230-Volts Nominal
LO (switch bar in left holes)	90 to 110 volts	180 to 220 volts
M (switch bar in middle holes)	104 to 126 volts	208 to 252 volts
HI (switch bar in right holes)	112 to 136 volts	224 to 272 volts

Operating Temperature

The Type 453 is cooled by air drawn in at the rear and blown out through holes in the top and bottom covers. Adequate clearance on the top, bottom and rear must be provided to allow heat to be dissipated away from the instrument. The clearance provided by the feet at the bottom and rear should be maintained. If possible, allow about one inch of clearance on the top. Do not block or restrict the air flow from the air-escape holes in the cabinet.

A thermal cutout in this instrument provides thermal protection and disconnects the power to the instrument if the internal temperature exceeds a safe operating level. Operation of the instrument for extended periods without the covers may cause it to overheat and the thermal cutout to open more frequently. The air filter should be cleaned occasionally to allow the maximum amount of cooling air to enter the instrument. Cleaning instructions are given in Section 4.

The Type 453 can be operated where the ambient air temperature is between −15°C and +55°C. Derate the maximum operating temperature 1°C for each additional 1000 feet of altitude above 5000 feet. This instrument can be stored in ambient temperatures between −55°C and +75°C. After storage at temperatures beyond the operating limits, allow the chassis temperature to come within the operating limits before power is applied.

Rackmounting

Complete information for mounting the Type R453 in a cabinet rack is given in Section 10 of this manual.

CONTROLS AND CONNECTORS

A brief description of the function or operation of the front-, side- and rear-panel controls and connectors follows (see Fig. 2-4). More detailed information is given in this section under General Operating Information.

Cathode-Ray Tube

INTENSITY — Controls brightness of display.

FOCUS — Provides adjustment for a well-defined display.

SCALE ILLUM — Controls graticule illumination.

TRACE FINDER — Compresses display within graticule area independent of display position or applied signals.

Vertical (both channels except as noted)

VOLTS/DIV — Selects vertical deflection factor (VARIABLE control must be in CAL position for indicated deflection factor).

VARIABLE — Provides continuously variable deflection factor between the calibrated settings of the VOLTS/DIV switch.

UNCAL — Light indicates that the VARIABLE control is not in the CAL position.

POSITION — Controls vertical position of trace.

GAIN — Screwdriver adjustment to set gain of the Vertical Preamp. Line between adjustment and 20 mV VOLTS/DIV position indicates that gain should be set with VOLTS/DIV switch in this position.

Input Coupling (AC GND DC) — Selects method of coupling input signal to Vertical Deflection System.

AC: DC component of input signal is blocked. Low frequency limit (−3 dB point) is about 1.6 hertz.

GND: Input circuit is grounded (does not ground applied signal).

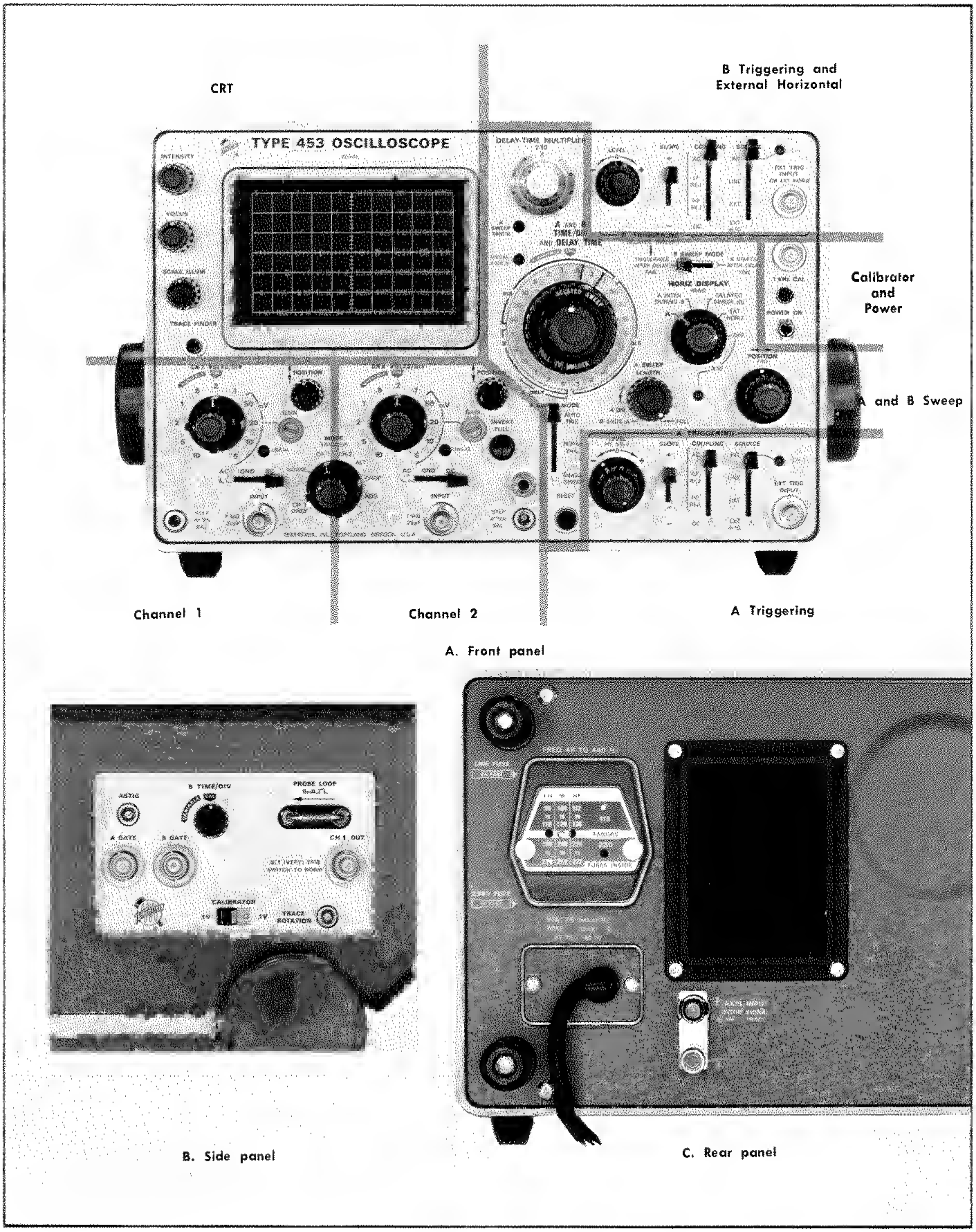


Fig. 2-4. Front-, side- and rear-panel controls and connectors.

	DC: All components of the input signal are passed to the Vertical Deflection System.
STEP ATTEN BAL	Screwdriver adjustment to balance Vertical Deflection System in the 5, 10 and 20 mV positions of the VOLTS/DIV switch.
INPUT	Vertical input connector for signal.
MODE	Selects vertical mode of operation. CH 1: The Channel 1 signal is displayed. CH 2: The Channel 2 signal is displayed. ALT: Dual trace display of signal on both channels. Display switched at end of each sweep. CHOP: Dual trace display of signal on both channels. Approximately one-microsecond segments from each channel displayed at a repetition rate of about 500 kilohertz. ADD: Channel 1 and 2 signals are algebraically added and the algebraic sum is displayed on the CRT.
TRIGGER	Selects source of internal trigger signal from vertical system. NORM: Sweep circuits triggered from displayed channel(s). Channel 1 signal available at CH 1 OUT connector. CH 1 ONLY: Sweep circuits triggered only from signal applied to the Channel 1 INPUT connector. No signal available at CH 1 OUT connector. CH 1 lights, located beside A and B SOURCE switches indicate when the TRIGGER switch is in the CH 1 ONLY position.
INVERT (CH 2 only)	Inverts the Channel 2 signal when pulled out.

A and B Triggering (both where applicable)

EXT TRIG INPUT	Input connector for external trigger signal. Connector in B Triggering section of front panel also serves as external horizontal input when HORIZ DISPLAY switch is in EXT HORIZ position and B SOURCE switch is in EXT position.
SOURCE	Selects source of trigger signal. INT: Internal trigger signal obtained from Vertical Deflection System. When CH 1 light is on, trigger signal is obtained only from the Channel 1 input signal; when the light is off, the trigger signal is obtained from the displayed channel(s). Source of internal trigger signal is selected by the TRIGGER switch. LINE: Trigger signal obtained from a sample of the line voltage applied to this instrument. EXT: Trigger signal obtained from an external signal applied to the EXT TRIG INPUT connector. EXT ÷ 10: Attenuates external trigger signal approximately 10 times.
CH 1	Light indicates that the internal trigger signal is obtained only from the signal connected to the Channel 1 INPUT connector (see TRIGGER switch).
COUPLING	Determines method of coupling trigger signal to trigger circuit. AC: Rejects DC and attenuates signals below about 30 hertz. Accepts signals between about 30 hertz and 50 megahertz. LF REJ: Rejects DC and attenuates signals below about 30 kilohertz. Accepts signals between about 30 kilohertz and 50 megahertz. HF REJ: Accepts signals between about 30 hertz and 50 kilohertz; rejects DC and attenuates signals outside the above range. DC: Accepts all trigger signals from DC to 50 megahertz or greater.
SLOPE	Selects portion of trigger signal which starts the sweep. +: Sweep can be triggered from positive-going portion of trigger signal. —: Sweep can be triggered from negative-going portion of trigger signal.
LEVEL	Selects amplitude point on trigger signal at which sweep is triggered.
HF STAB (A Triggering only)	Decreases display jitter for high-frequency signals. Has negligible effect at lower sweep rates.

A and B Sweep

DELAY-TIME MULTIPLIER	Provides variable sweep delay between 0.20 and 10.20 times the delay time indicated by the A TIME/DIV switch.
A SWEEP TRIG'D	Light indicates that A sweep is triggered and will produce a stable display with correct INTENSITY and POSITION control settings.
UNCAL A OR B	Light indicates that either the A or B VARIABLE control is not in the CAL position.
A AND B TIME/DIV AND DELAY TIME	A TIME/DIV switch (clear plastic flange) selects the sweep rate of the A sweep circuit for A sweep only operation and selects the basic delay time (to be multiplied by DELAY-TIME MULTIPLIER dial setting) for delayed sweep operation. B TIME/DIV (DELAYED SWEEP) switch selects sweep rate of the B sweep circuit

for delayed sweep operation only. VARIABLE controls must be in CAL positions for calibrated sweep rates.

A VARIABLE — Provides continuously variable A sweep rate to at least 2.5 times setting of the A TIME/DIV switch. A sweep rate is calibrated when control is set fully clockwise to CAL.

B SWEEP MODE — Selects B sweep operation mode.

TRIGGERABLE AFTER DELAY TIME: B sweep circuit will not produce a sweep until a trigger pulse is received following the delay time selected by the DELAY TIME (A TIME/DIV) switch and the DELAY-TIME MULTIPLIER dial.

B STARTS AFTER DELAY TIME: B sweep circuit runs immediately following delay time selected by the DELAY TIME switch and DELAY-TIME MULTIPLIER dial.

HORIZ DISPLAY — Selects horizontal mode of operation.

A: Horizontal deflection provided by A sweep. B sweep inoperative.

A INTEN DURING B: Sweep rate determined by A TIME/DIV switch. An intensified portion appears on the sweep during the B sweep time. This position provides a check of the duration and position of the delayed sweep (B) with respect to the delaying sweep (A).

DELAYED SWEEP (B): Sweep rate determined by B TIME/DIV switch with the delay time determined by the setting of the DELAY TIME (A TIME/DIV) switch and the DELAY-TIME MULTIPLIER dial. Sweep mode determined by B SWEEP MODE switch.

EXT HORIZ: Horizontal deflection provided by an external signal.

MAG — Increases sweep rate to ten times setting of A or B TIME/DIV switch by horizontally expanding the center division of the display. Light indicates when magnifier is on.

A SWEEP MODE — Determines the operating mode for A sweep.

AUTO TRIG: Sweep initiated by the applied trigger signal using the A Triggering controls when the trigger signal repetition rate is above about 20 hertz. For lower repetition rates or when there is no trigger signal, the sweep free runs at the sweep rate selected by the A TIME/DIV switch to produce a bright reference trace.

NORM TRIG: Sweep initiated by the applied trigger signal using the A Triggering controls. No trace is displayed when there is no trigger signal.

SINGLE SWEEP: After a sweep is displayed, further sweeps cannot be presented until the RESET button is pressed. Display is triggered as for NORM operation using the A Triggering controls.

RESET — When the RESET button is pressed (SINGLE SWEEP mode), a single display will be presented (with correct triggering) when the next trigger pulse is received. RESET light (inside RESET button) remains on until a trigger is received and the sweep is completed. RESET button must be pressed before another sweep can be presented.

A SWEEP LENGTH — Adjusts length of A sweep. In the FULL position (clockwise detent), the sweep is about 11 divisions long. As the control is rotated counterclockwise, the length of A sweep is reduced until it is less than four divisions long just before the detent in the fully-counterclockwise position is reached. In the B ENDS A position (counterclockwise detent), the A sweep is reset at the end of the B sweep to provide the fastest possible sweep repetition rate for delayed sweep displays.

POSITION — Controls horizontal position of trace.

FINE — Provides more precise horizontal position adjustment.

1 kHz CAL — Calibrator output connector.

POWER ON — Light: Indicates that POWER switch is on and the instrument is connected to a line voltage source.

Switch: Controls power to the instrument.

Side Panel

ASTIG — Screwdriver adjustment used in conjunction with the FOCUS control to obtain a well-defined display. Does not require readjustment in normal use.

B TIME/DIV-VARIABLE — Provides continuously variable sweep rate to at least 2.5 times setting of B TIME/DIV switch. B sweep rate is calibrated when control is set fully clockwise to CAL.

PROBE LOOP — Current loop providing five-milliampere square-wave current from calibrator circuit.

A GATE — Output connector providing a rectangular pulse coincident with A sweep.

B GATE — Output connector providing a rectangular pulse coincident with B sweep.

CH 1 OUT — Output connector providing a sample of the signal applied to the Channel 1 INPUT connector when the TRIGGER switch is in the NORM position.

CALIBRATOR	Switch selects output voltage of Calibrator. 1-volt or 0.1-volt square wave available.
TRACE ROTATION	Screwdriver adjustment to align trace with horizontal graticule lines.

Rear Panel

Z AXIS INPUT	Input connector for intensity modulation of the CRT display.
Line Voltage Selector	Switching assembly to select the nominal operating voltage and the line voltage range. The assembly also includes the line fuses.
	Voltage Selector: Selects nominal operating voltage range (115 V or 230 V).
	Range Selector: Selects line voltage range (low, medium, high).

FIRST-TIME OPERATION

The following steps will demonstrate the use of the controls and connectors of the Type 453. It is recommended that this procedure be followed completely for familiarization with this instrument.

Setup Information

1. Set the front-panel controls as follows:

CRT Controls

INTENSITY	Counterclockwise
FOCUS	Midrange
SCALE ILLUM	Counterclockwise

Vertical Controls (both channels if applicable)

VOLTS/DIV	20 mV
VARIABLE	CAL
POSITION	Midrange
INPUT COUPLING	DC
MODE	CH 1
TRIGGER	NORM
INVERT	Pushed in

Triggering Controls (both A and B if applicable)

LEVEL	Clockwise (+)
SLOPE	+
COUPLING	AC
SOURCE	INT

Sweep Controls

DELAY-TIME MULTIPLIER	0.20
A and B TIME/DIV	.5 ms
A VARIABLE	CAL
B SWEEP MODE	B STARTS AFTER DELAY TIME
HORIZ DISPLAY	A
MAG	OFF
POSITION	Midrange
A SWEEP LENGTH	FULL
A SWEEP MODE	AUTO TRIG
POWER	OFF

Side-Panel Controls

B TIME/DIV VARIABLE	CAL
CALIBRATOR	.1 V

2. Connect the Type 453 to a power source that meets the voltage and frequency requirements of the instrument. If the available line voltage is outside the limits of the Line Voltage Selector assembly position (on rear panel), see Operating Voltage in this section.

3. Set the POWER switch to ON. Allow about five minutes warmup so the instrument reaches a normal operating temperature before proceeding.

CRT Controls

4. Advance the INTENSITY control until the trace is at the desired viewing level (near midrange).

5. Connect the 1 kHz CAL connector to the Channel 1 INPUT connector with a BNC cable.

6. Turn the A LEVEL control toward 0 until the display becomes stable. Note that the A SWEEP TRIG'D light is on when the display is stable.

7. Adjust the FOCUS control for a sharp, well-defined display over the entire trace length. (If focused display cannot be obtained, see Astigmatism Adjustment in this section.)

8. Disconnect the input signal and move the trace with the Channel 1 POSITION control so it coincides with one of the horizontal graticule lines. If the trace is not parallel with the graticule line, see Trace Alignment Adjustment in this section.

9. Rotate the SCALE ILLUM control throughout its range and notice that the graticule lines are illuminated as the control is turned clockwise (most obvious with mesh or smoke-gray filter installed). Set control so graticule lines are illuminated as desired.

Vertical Controls

10. Change the CH 1 VOLTS/DIV switch from 20 mV to 5 mV. If the vertical position of the trace shifts, see Step Attenuator Balance in this section.

11. Set the CH 1 VOLTS/DIV switch to 20 mV and set the Channel 1 Input Coupling switch to AC. Connect the 1 kHz CAL connector to both the Channel 1 and 2 INPUT connectors with two BNC cables and a BNC T connector.

NOTE

If the BNC cables and BNC T connector are not available, make the following changes in the procedure. Place the BNC jack post (supplied accessory) on the 1 kHz CAL connector and connect the two 10X probes (supplied accessories) to

the Channel 1 and 2 INPUT connectors. Connect the probe tips to the BNC jack post. Set the CALIBRATOR switch (on side-panel) to 1 V.

12. Turn the Channel 1 POSITION control to center the display. The display is a square wave, five divisions in amplitude with about five cycles displayed on the screen. If the display is not five divisions in amplitude, see Vertical Gain Adjustment in this section.

13. Set the Channel 1 Input Coupling switch to GND and position the trace to the center horizontal line.

14. Set the Channel 1 Input Coupling switch to DC. Note that the baseline of the waveform remains at the center horizontal line (ground reference).

15. Set the Channel 1 Input Coupling switch to AC. Note that the waveform is centered about the center horizontal line.

16. Turn the Channel 1 VARIABLE control throughout its range. Note that the UNCAL light comes on when the VARIABLE control is moved from the CAL position (fully clockwise). The deflection should be reduced to about two divisions. Return the VARIABLE control to CAL.

17. Set the MODE switch to CH 2.

18. Turn the Channel 2 POSITION control to center the display. The display will be similar to the previous display for Channel 1. Check Channel 2 step attenuator balance and gain as described in steps 10 through 12. The Channel 2 Input Coupling switch and VARIABLE control operate as described in steps 13 through 16.

19. Set both VOLTS/DIV switches to 50 mV.

20. Set the MODE switch to ALT and position the Channel 1 waveform to the top of the graticule area and the Channel 2 waveform to the bottom of the graticule area. Turn the A TIME/DIV switch throughout its range. Note that the display alternates between channels at all sweep rates.

21. Set the MODE switch to CHOP and the A TIME/DIV switch to 10 μs. Note the switching between channels as shown by the segmented trace. Set the TRIGGER switch to CH 1 ONLY; the trace should appear more solid, since it is no longer triggered on the between-channel switching transients. Turn the A TIME/DIV switch throughout its range. A dual-trace display is presented at all sweep rates, but unlike ALT, both channels are displayed on each trace on a time-sharing basis. Return the A TIME/DIV switch to .5 ms.

22. Set the MODE switch to ADD. The display should be four divisions in amplitude. Note that either POSITION control moves the display.

23. Pull the INVERT switch. The display is a straight line indicating that the algebraic sum of the two signals is zero (if the Channel 1 and 2 gain is correct).

24. Set either VOLTS/DIV switch to 20 mV. The square-wave display indicates that the algebraic sum of the two signals is no longer zero. Return the MODE switch to CH 1 and both VOLTS/DIV switches to .2 (if using 10× probes, set both VOLTS/DIV switches to 20 mV). Push in the INVERT switch.

Triggering

25. Set the CALIBRATOR switch to 1 V. Rotate the A LEVEL control throughout its range. The display free runs at the extremes of rotation. Note that the A SWEEP TRIG'D light is on only when the display is triggered.

26. Set the A SWEEP MODE switch to NORM TRIG. Again rotate the A LEVEL control throughout its range. A display is presented only when correctly triggered. The A SWEEP TRIG'D light operates as in AUTO TRIG. Return the A SWEEP MODE switch to AUTO TRIG.

27. Set the A SLOPE switch to —. The trace starts on the negative part of the square wave. Return the switch to +; the trace starts with the positive part of the square wave.

28. Set the A COUPLING switch to DC. Turn the Channel 1 POSITION control until the display becomes unstable (only part of square wave visible). Return the A COUPLING switch to AC; the display is again stable. Since changing trace position changes DC level, this shows how DC level changes affect DC trigger coupling. Return the display to the center of the screen.

29. Set the MODE switch to CH 2; the display should be stable. Remove the signal connected to Channel 1; the display free runs. Set the TRIGGER switch to NORM; the display is again stable. Note that the CH 1 lights in A and B Triggering go out when the TRIGGER switch is changed to NORM.

30. Connect the Calibrator signal to both the Channel 2 INPUT and A EXT TRIG INPUT connectors. Set the A SOURCE switch to EXT. Operation of the LEVEL, SLOPE and COUPLING controls for external triggering are the same as described in steps 25 through 28.

31. Set the A SOURCE switch to EXT ÷ 10. Operation is the same as for EXT. Note that the A LEVEL control has less range in this position, indicating trigger signal attenuation. Return the A SOURCE switch to INT.

32. Operation of the B Triggering controls is similar to A Triggering.

Normal and Magnified Sweep

33. Set the A TIME/DIV switch to 5 ms and the MAG switch to ×10. The display should be similar to that obtained with the A TIME/DIV switch set to .5 ms and the MAG switch to OFF.

34. Turn the horizontal POSITION control throughout its range; it should be possible to position the display across the complete graticule area. Now turn the FINE control. The display moves a smaller amount and allows more precise positioning. Return the A TIME/DIV switch to .5 ms, the MAG switch to OFF and return the start of the trace to the left graticule line.

Delayed Sweep

36. Pull the DELAYED SWEEP knob out and turn it to 50 μs (DELAY TIME remains at .5 ms). Set the HORIZ DISPLAY switch to A INTEN DURING B. An intensified portion, about one division in length, should be shown at the start of the trace. Rotate the DELAY-TIME MULTIPLIER dial throughout its range; the intensified portion should move along the display.

37. Set the B SWEEP MODE switch to TRIGGERABLE AFTER DELAY TIME. Again rotate the DELAY-TIME MULTIPLIER dial throughout its range and note that the intensified portion appears to jump between positive slopes of the display. Set the B SLOPE switch to —; the intensified portion begins on the negative slope. Rotate the B LEVEL control; the intensified portion of the display disappears when the B LEVEL control is out of the triggerable range. Return the B LEVEL control to 0.

38. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). Rotate the DELAY-TIME MULTIPLIER dial throughout its range; about one-half cycle of the waveform should be displayed on the screen (leading edge visible only at high INTENSITY control setting). The display remains stable on the screen, indicating that the B sweep is triggered.

39. Set the B SWEEP MODE switch to B STARTS AFTER DELAY TIME. Rotate the DELAY-TIME MULTIPLIER dial throughout its range; the display moves continously across the screen as the control is rotated.

40. Rotate the DELAY-TIME MULTIPLIER dial fully counterclockwise and set the HORIZ DISPLAY switch to A INTEN DURING B. Rotate the A SWEEP LENGTH control counterclockwise; the length of the display decreases. Set the control to the B ENDS A position; now the display ends after the intensified portion. Rotate the DELAY-TIME MULTIPLIER dial and note that the sweep length increases as the display moves across the screen. Return the A SWEEP LENGTH control to FULL and the HORIZ DISPLAY switch to A.

Single Sweep

41. Set the A SWEEP MODE switch to SINGLE SWEEP. Remove the Calibrator signal from the Channel 2 INPUT connector. Press the RESET button; the RESET light should come on and remain on. Again apply the signal to the Channel 2 INPUT connector; a single trace should be presented and the RESET light should go out. Return the A SWEEP MODE switch to AUTO TRIG.

External Horizontal

42. Connect the Calibrator signal to both the Channel 2 INPUT and EXT HORIZ (B EXT TRIG INPUT) connectors. Set the B SOURCE switch to EXT, B COUPLING switch to DC and the HORIZ DISPLAY switch to EXT HORIZ. Increase the INTENSITY control setting until the display is visible (two dots displayed diagonally). The display should be five divisions vertically and about 3.7 divisions horizontally. Set the B SOURCE switch to EXT ÷ 10. The display should be reduced ten times horizontally. The display can be positioned horizontally with the horizontal POSITION or FINE control and vertically with the Channel 2 POSITION control.

43. Connect the Calibrator signal to both the Channel 1 and 2 INPUT connectors. Set the TRIGGER switch to CH 1 ONLY and the B SOURCE switch to INT.

44. The display should be five divisions vertically and horizontally. The display can be positioned horizontally with the Channel 1 POSITION control and vertically with the Channel 2 POSITION control.

45. Change the CH 1 VOLTS/DIV switch to .5. The display is reduced to two divisions horizontally. Now set the CH 2 VOLTS/DIV switch to .5. The display is reduced to two divisions vertically.

Trace Finder

46. Set the CH 1 and CH 2 VOLTS/DIV switches to 10 mV. The display is not visible since it exceeds the scan area of the CRT.

47. Press the TRACE FINDER button. Note that the display is returned to the display area. While holding the TRACE FINDER button depressed, increase the vertical and horizontal deflection factors until the display is reduced to about two divisions vertically and horizontally. Adjust the Channel 1 and 2 POSITION controls to center the display about the center lines of the graticule. Release the TRACE FINDER and note that the display remains within the viewing area. Disconnect the applied signal.

48. Reduce the INTENSITY control setting to normal, B SOURCE switch to INT and set the HORIZ DISPLAY switch to A.

Z-Axis Input

49. If an external signal is available (five volts peak to peak minimum) the function of the Z AXIS INPUT circuit can be demonstrated. Connect the external signal to both the Channel 2 INPUT connector and the Z AXIS INPUT binding posts. Set the A TIME/DIV switch to display about five cycles of the waveform. The positive peaks of the waveform should be blanked and the negative peaks intensified, indicating intensity modulation.

50. This completes the basic operating procedure for the Type 453. Instrument operation not explained here, or operations which need further explanation are discussed under General Operating Information.

CONTROL SETUP CHART

Fig. 2-5 shows the front, side and rear panels of the Type 453. This chart can be reproduced and used as a test-setup record for special measurements, applications or procedures, or it may be used as a training aid for familiarization with this instrument.

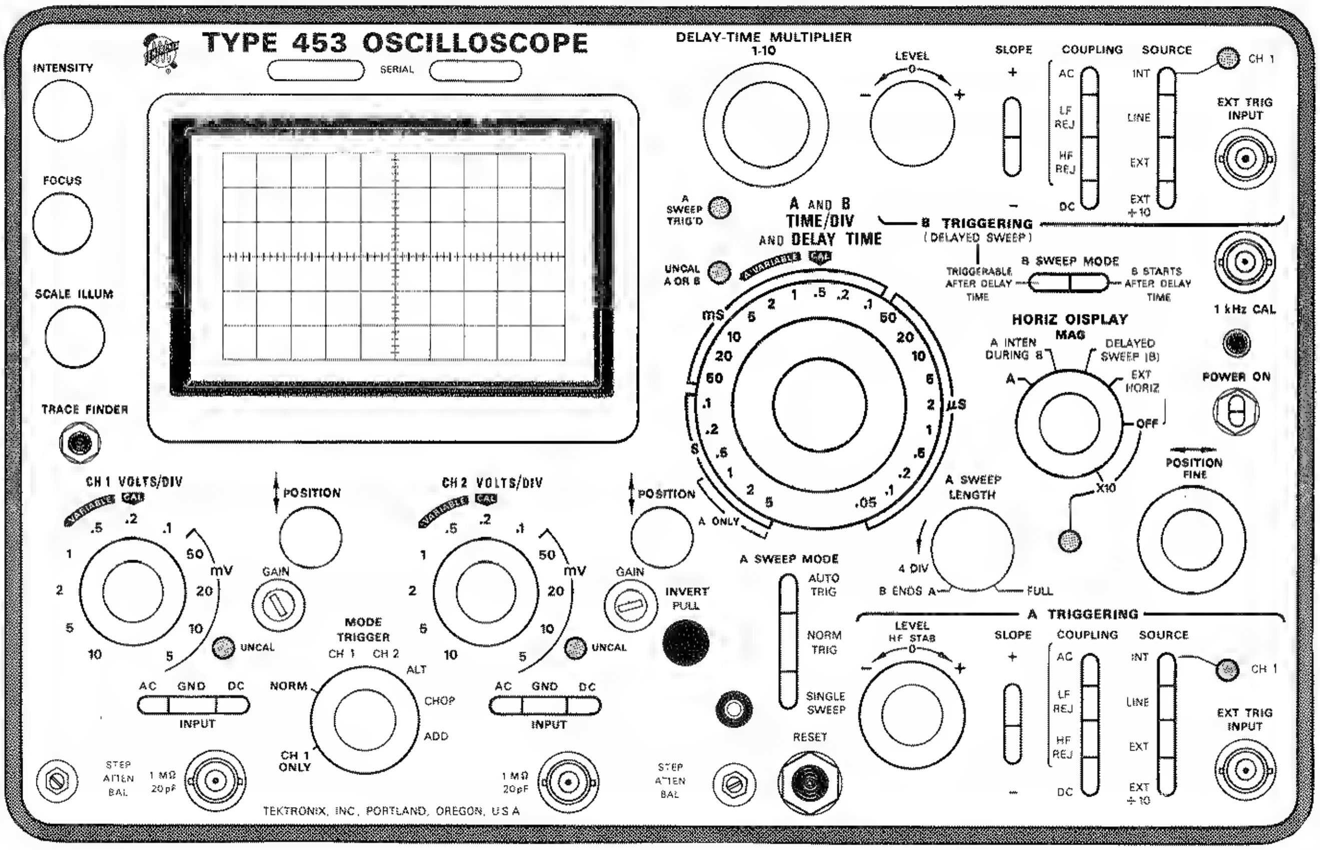
GENERAL OPERATING INFORMATION

Intensity Control

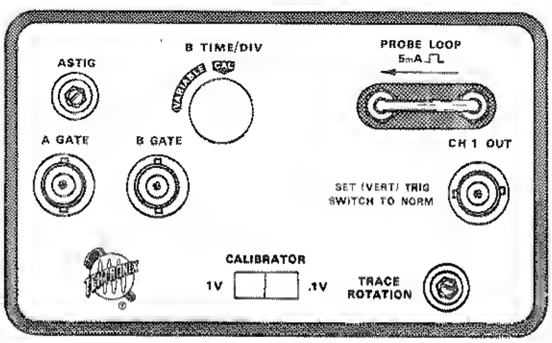
The setting of the INTENSITY control may affect the correct focus of the display. Slight readjustment of the FOCUS control may be necessary when the intensity level is changed. To protect the CRT phosphor, do not turn the INTENSITY control higher than necessary to provide a satisfactory display. The light filters reduce the observed light output from the CRT. When using these filters, avoid advancing the INTENSITY control to a setting that may burn the phosphor. When the highest intensity display is desired, remove the filters and use the clear faceplate protector. Also, be careful that the INTENSITY control is not set too high when changing the TIME/DIV switch from a fast to a slow sweep rate, or when changing the HORIZ DISPLAY switch from EXT HORIZ operation to the normal sweep mode.

Astigmatism Adjustment

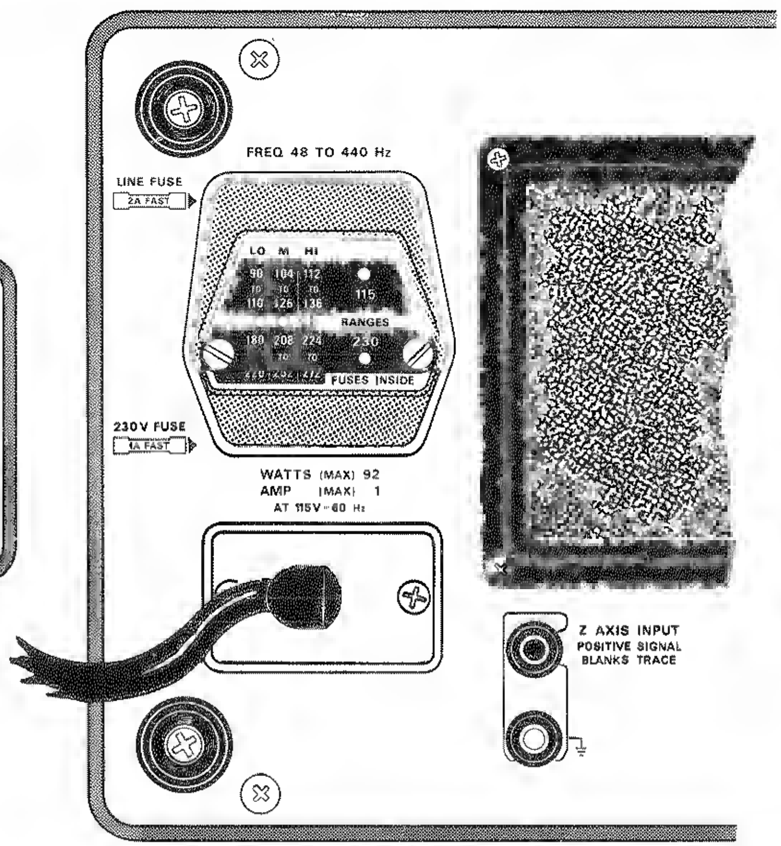
If a well-defined trace cannot be obtained with the FOCUS control, adjust the ASTIG adjustment (side panel) as follows.



A. Front panel



B. Side panel



C. Rear panel

Fig. 2-5. Control setup chart for the Type 453.

NOTE

To check for proper setting of the ASTIG adjustment, slowly turn the FOCUS control through the optimum setting. If the ASTIG adjustment is correctly set, the vertical and horizontal portions of the trace will come into sharpest focus at the same position of the FOCUS control. This setting of the ASTIG adjustment should be correct for any display. However, it may be necessary to reset the FOCUS control slightly when the INTENSITY control is changed.

1. Connect a 1 V Calibrator signal to either channel and set the VOLTS/DIV switch of that channel to present a two-division display. Set the MODE switch to display the channel selected.

2. Set the TIME/DIV switch to .2 ms.

3. With the FOCUS control and ASTIG adjustment set to midrange, adjust the INTENSITY control so the rising portion of the display can be seen.

4. Set the ASTIG adjustment so the horizontal and vertical portions of the display are equally focused, but not necessarily well focused.

5. Set the FOCUS control so the vertical portion of the trace is as thin as possible.

6. Repeat steps 4 and 5 for best overall focus. Make final check at normal intensity.

Graticule

The graticule of the Type 453 is internally marked on the faceplate of the CRT to provide accurate, no-parallax measurements. The graticule is marked with six vertical and 10 horizontal divisions. Each division is 0.8 centimeter square. In addition, each major division is divided into five minor divisions at the center vertical and horizontal lines. The vertical gain and horizontal timing are calibrated to the graticule so accurate measurements can be made from the CRT. The illumination of the graticule lines can be varied with the SCALE ILLUM control.

Fig. 2-6 shows the graticule of the Type 453 and defines the various measurement lines. The terminology defined here will be used in all discussions involving graticule measurements.

Trace Alignment Adjustment

If a free-running trace is not parallel to the horizontal graticule lines, set the TRACE ROTATION adjustment as follows. Position the trace to the center horizontal line. Adjust the TRACE ROTATION adjustment (side panel) so the trace is parallel with the horizontal graticule lines.

Light Filter

The mesh filter provided with the Type 453 provides shielding against radiated EMI (electro-magnetic interference) from the face of the CRT. It also serves as a light filter to make the trace more visible under ambient light conditions. To remove the filter, press down at the bottom of the frame and pull the top of the filter away from the CRT faceplate (see Fig. 2-7).

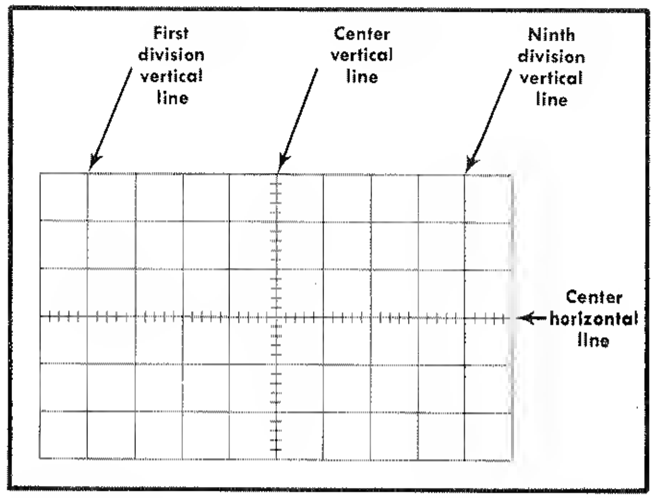


Fig. 2-6. Definition of measurement lines on Type 453 graticule.

The tinted light filter minimizes light reflections from the face of the CRT to improve contrast when viewing the display under high ambient light conditions. A clear plastic faceplate protector is also provided with this instrument for use when neither the mesh nor the tinted filter is used. The clear faceplate protector provides the best display for waveform photographs. It is also preferable for viewing high writing rate displays.

A filter or the faceplate protector should be used at all times to protect the CRT faceplate from scratches. The faceplate protector and the tinted filter mount in the same holder.

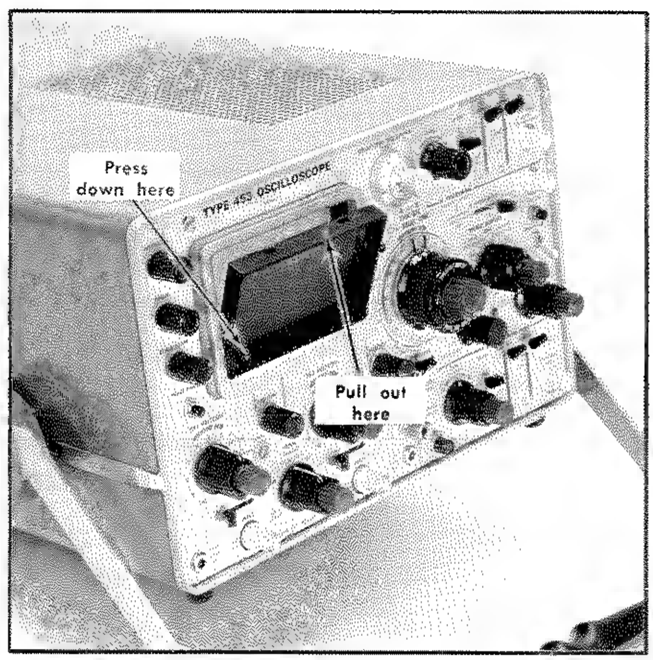


Fig. 2-7. Removing the filter or faceplate protector.

To remove the light filter or faceplate protector from the holder, press it out to the rear. They can be replaced by snapping them back into the holder.

Trace Finder

The TRACE FINDER provides a means of locating a display which overscans the viewing area either vertically or horizontally. When the TRACE FINDER button is pressed, the display is compressed within the graticule area. To locate and reposition an overscanned display, use the following procedure.

1. Press the TRACE FINDER button.

2. While the TRACE FINDER button is held depressed, increase the vertical and horizontal deflection factors until the vertical deflection is reduced to about two divisions and the horizontal deflection is reduced to about four divisions (the horizontal deflection needs to be reduced only when in the external horizontal mode of operation).

3. Adjust the vertical and horizontal POSITION controls to center the display about the vertical and horizontal center lines.

4. Release the TRACE FINDER button; the display should remain within the viewing area.

Vertical Channel Selection

Either of the input channels can be used for single-trace displays. Apply the signal to the desired INPUT connector and set the MODE switch to display the channel used. However, since CH 1 ONLY triggering is provided only in Channel 1 and the invert feature only in Channel 2, the correct channel must be selected to take advantage of these features. For dual-trace displays, connect the signals to both INPUT connectors and set the MODE switch to one of the dual-trace positions.

Vertical Gain Adjustment

To check the gain of either channel, set the VOLTS/DIV switch to 20 mV. Set the CALIBRATOR switch to .1 V and connect the 1 kHz CAL connector to the INPUT of the channel used. The vertical deflection should be exactly five divisions. If not, adjust the front-panel GAIN adjustment for exactly five divisions of deflection.

NOTE

If the gain of the two channels must be closely matched (such as for ADD mode operation), the ADJUSTMENT procedure given in the Calibration section should be used.

The best measurement accuracy when using probes is provided if the GAIN adjustment is made with the probes installed (set the CALIBRATOR switch to 1 V). Also, to provide the most accurate measurements, calibrate the vertical gain of the Type 453 at the temperaure at which the measurement is to be made.

Step Attenuator Balance

To check the step attenuator balance of either channel, set the Input Coupling switch to GND and set the A SWEEP MODE swich to AUTO TRIG to provide a free-running trace. Change the VOLTS/DIV switch from 20 mV to 5 mV. If the trace moves vertically, adjust the front-panel STEP ATTEN BAL adjustment as follows (allow at least 10 minutes warm up before performing this adjustment).

1. With the Input Coupling switch set to GND and the VOLTS/DIV switch set to 20 mV, move the trace to the center horizontal line of the graticule with the vertical POSITION control.

2. Set the VOLTS/DIV switch to 5 mV and adjust the STEP ATTEN BAL adjustment to return the trace to the center horizonal line.

3. Recheck step attenuator balance and repeat adjustment until no trace shift occurs as the VOLTS/DIV switch is changed from 20 mV to 5 mV.

Signal Connections

In general, probes offer the most convenient means of connecting a signal to the input of the Type 453. The Tektronix probes are shielded to prevent pickup of electrostatic interference. A 10× attenuator probe offers a high input impedance and allows the circuit under test to perform very close to normal operating conditions. However, a 10× probe also attenuates the input signal 10 times. The Tektronix P6045 Field Effect Transistor probe and accessory power supply offer the same high-input impedance as the 10× probes. However, it is particularly useful since it provides wide-band operation while presenting no attenuation (1× gain) and a low input capacitance. To obtain maximum bandwidth when using the probes, observe the grounding considerations given in the probe manual. The probe-to-connector adapters and the bayonet-ground tip provide the best frequency response. Remember that a ground strap only a few inches in length can produce several percent of ringing when operating at the higher frequency limit of this system. See your Tektronix, Inc. catalog for characteristics and compatibitlity of probes for use with this system.

In high-frequency applications requiring maximum overall bandwidth, use coaxial cables terminated at both ends in their characteristic impedance. See the discussion on coaxial cables in this section for more information.

High-level, low-frequency signals can be connected directly to the Type 453 INPUT connectors with short unshielded leads. This coupling method works best for signals below about one kilohertz and deflection factors above one volt/division. When this method is used, establish a common ground between the Type 453 and the equipment under test. Attempt to position the leads away from any source of interference to avoid errors in the display. If interference is excessive with unshielded leads, use a coaxial cable or a probe.

Loading Effect of the Type 453

As nearly as possible, simulate actual operating conditions in the equipment under test. Otherwise, the equipment under test may not produce a normal signal. The 10× attenuator probe and field effect transistor probe mentioned previously offer the least circuit loading. See the probe instruction manual for loading characteristics of the individual probes.

When the signal is coupled directly to the input of the Type 453, the input impedance is about one megohm paralleled by about 20 pF. When the signal is coupled to the input through a coaxial cable, the effective input capacitance depends upon the type and length of cable used. See the following discussion for information on obtaining maximum frequency response with coaxial cables.

Coaxial Cable Considerations

The signal cables used to connect the signal to the Type 453 INPUT connectors have a large effect on the accuracy of the displayed high-frequency waveform. To maintain the high-frequency characteristics of the applied signal, high-quality low-loss coaxial cable should be used. The cable should be terminated at the Type 453 INPUT connector in its characteristic impedance. If it is necessary to use cables with differing characteristic impedances, use suitable impedance-matching devices to provide the correct transition, with minimum loss, from one impedance to the other.

The characteristic impedance, velocity of propagation and nature of signal losses in a coaxial cable are determined by the physical and electrical characteristics of the cable. Losses caused by energy dissipation in the dielectric are proportional to the signal frequency. Therefore, much of the high-frequency information in a fast-rise pulse can be lost in only a few feet of interconnecting cable if it is not the correct type. To be sure of the high-frequency response of the system when using cables longer than about five feet, observe the transient response of the Type 453 and the interconecting cable with a fast-rise pulse generator (generator risetime less than 0.5 nanoseconds).

Input Coupling

The Channel 1 and 2 Input Coupling switches allow a choice of input coupling. The type of display desired will determine the coupling used.

The DC position can be used for most applications. However, if the DC component of the signal is much larger than the AC component, the AC position will probably provide a better display. DC coupling should be used to display AC signals below about 16 hertz as they will be attenuated in the AC position.

In the AC position, the DC component of the signal is blocked by a capacitor in the input circuit. The low-frequency response in the AC position is about 1.6 hertz (—3 dB point). Therefore, some low-frequency distortion can be expected near this frequency limit. Distortion will also appear in square waves which have low-frequency components.

The GND position provides a ground reference at the input of the Type 453. The signal applied to the input connector is internally disconnected but not grounded. The input circuit is held at ground potential, eliminating the need to externally ground the input to establish a DC ground reference.

The GND position can also be used to pre-charge the coupling capacitor to the average voltage level of the signal applied to the INPUT connector. This allows measurement of only the AC component of signals having both AC and DC components. The pre-charging network incorporated in this unit allows the input-coupling capacitor to charge to the DC source voltage level when the Input Coupling switch is set to GND. The procedure for using this feature is as follows:

1. Before connecting the signal containing a DC component to the Type 453 INPUT connector, set the Input Coupling switch to GND. Then connect the signal to the INPUT connector.

2. Wait about one second for the coupling capacitor to charge.

3. Set the Input Coupling switch to AC. The trace (display) will remain on the screen and the AC component of the signal can be measured in the normal manner.

Deflection Factor

The amount of vertical deflection produced by a signal is determined by the signal amplitude, the attenuation factor of the probe (if used), the setting of the VOLTS/DIV switch and the setting of the VARIABLE VOLTS/DIV control. The calibrated deflection factors indicated by the VOLTS/DIV switches apply only when the VARIABLE control is set to the CAL position.

The VARIABLE VOLTS/DIV control provides variable (uncalibrated) vertical deflection between the calibrated settings of the VOLTS/DIV switch. The VARIABLE control extends the maximum vertical deflection factor of the Type 453 to at least 25 volts/division (10 volts position).

Dual-Trace Operation

Alternate Mode. The ALT position of the MODE switch produces a display which alternates between Channel 1 and 2 with each sweep of the CRT. Although the ALT mode can be used at all sweep rates, the CHOP mode provides a more satisfactory display at sweep rates below about 50 microseconds/division. At these slower sweep rates, alternate mode switching becomes visually perceptible.

Proper internal triggering in the ALT mode can be obtained in either the NORM or CH 1 ONLY positions of the TRIGGER switch. When in the NORM position, the sweep is triggered from the signal on each channel. This provides a stable display of two unrelated signals, but does not indicate the time relationship between the signals. In the CH 1 ONLY position, the two signals are displayed showing true time relationship. If the signals are not time related, the Channel 2 waveform will be unstable in the CH 1 ONLY position.

Chopped Mode. The CHOP position of the MODE switch produces a display which is electronically switched between channels. In general, the CHOP mode provides the best display at sweep rates slower than about 50 microseconds/division, or whenever dual-trace, single-shot phenomena are to be displayed. At faster sweep rates the chopped switching becomes apparent and may interfere with the display.

Proper internal triggering for the CHOP mode is provided with the TRIGGER switch set to CH 1 ONLY. If the NORM position is used, the sweep circuits are triggered from the between-channel switching signal and both waveforms will

be unstable. External triggering provides the same result as CH 1 ONLY triggering.

Two signals which are time-related can be displayed in the chopped mode showing true time relationship. If the signals are not time-related, the Channel 2 display will appear unstable. Two single-shot, transient, or random signals which occur within the time interval determined by the TIME/DIV switch (10 times sweep rate) can be compared using the CHOP mode. To correctly trigger the sweep for maximum resolution, the Channel 1 signal must precede the Channel 2 signal. Since the signals show true time relationship, time-difference measurements can be made.

Channel 1 Output and Cascaded Operation

If a lower deflection factor than provided by the VOLTS/DIV switches is desired, Channel 1 can be used as a wide-band preamplifier for Channel 2. Apply the input signal to the Channel 1 INPUT connector. Connect a 50-ohm BNC cable (18-inch or shorter cable for maximum cascaded frequency response) between the CH 1 OUT (side panel) and the Channel 2 INPUT connectors. Set the MODE switch to CH 2 and the TRIGGER switch to NORM. With both VOLTS/DIV switches set to 5 mV, the deflection factor will be less than one millivolt/division.

To provide calibrated one millivolt/division deflection factor, connect the .1 volt Calibrator signal to the Channel 1 INPUT connector. Set the CH 1 VOLTS/DIV switch to .1 and the CH 2 VOLTS/DIV switch to 5 mV. Adjust the Channel 2 VARIABLE VOLTS/DIV control to produce a display exactly five divisions in amplitude. The cascaded deflection factor is determined by dividing the CH 1 VOLTS/DIV switch setting by 5 (CH 2 VOLTS/DIV switch and VARIABLE control remain as set above). For example, with the CH 1 VOLTS/DIV switch set to 5 mV the calibrated deflection factor will be 1 millivolt/division; CH 1 VOLTS/DIV switch set to 10 mV, 2 millivolts/division, etc.

The following operating considerations and basic applications may suggest other uses for this feature.

1. If AC coupling is desired, set the Channel 1 Input Coupling switch to AC and leave the Channel 2 Input Coupling switch set to DC. When both Input Coupling switches are set to DC, DC signal coupling is provided.

2. Keep both vertical POSITION controls set near midrange. If the input signal has a DC level which necessitates one of the POSITION controls being turned away from midrange, correct operation can be obtained by keeping the Channel 2 POSITION control near midrange and using the Channel 1 POSITION control to position the trace near the desired location. Then, use the Channel 2 POSITION control for exact positioning. This method will keep both Input Preamps operating in their linear range.

3. The output voltage at the CH 1 OUT connector is at least 25 millivolts/division of CRT display in all CH 1 VOLTS/DIV switch positions.

4. The MODE switch and Channel 1 VARIABLE VOLTS/DIV control have no effect on the signal available at the CH 1 OUT connector.

5. The Channel 1 Input Preamp can be used as an impedance matching stage with or without voltage gain. The input resistance is one megohm and the output resistance is about 50 ohms.

6. The dynamic range of the Channel 1 Input Preamp is equal to about 20 times the CH 1 VOLTS/DIV setting. The CH 1 OUT signal is nominally at 0 volt DC for a 0 volt DC input level (Channel 1 POSITION control centered). The Chanel 1 POSITION control can be used to center the output signal within the dynamic range of the amplifier.

7. If dual-trace operation is used, the signal applied to the Channel 1 INPUT connector is displayed when Channel 1 is turned on. When Channel 2 is turned on, the amplified signal is displayed. Thus, Channel 1 trace can be used to monitor the input signal while the amplified signal is displayed by Channel 2.

8. In special applications where the flat frequency response of the Type 453 is not desired, a filter inserted between the CH 1 OUT and Channel 2 INPUT connector allows the oscilloscope to essentially take on the frequency response of the filter. Combined with method 7, the input can be monitored by Channel 1 and the filtered signal displayed by Channel 2.

9. By using Channel 1 as a 5× low-level voltage preamplifier (5 mV position), the Channel 1 signal available at the CH 1 OUT connector can be used for any application where a low-impedance preamplified signal is needed. Remember that if a 50-ohm load impedance is used, the signal amplitude will be about one-half.

Algebraic Addition

General. The ADD position of the MODE switch can be used to display the sum or difference of two signals, for common-mode rejection to remove an undesired signal or for DC offset (applying a DC voltage to one channel to offset the DC component of a signal on the other channel).

The common-mode rejection ratio of the Type 453 is greater than 20:1 at 20 megahertz for signal amplitudes up to eight times the VOLTS/DIV switch setting. Rejection ratios of 100:1 can typically be achieved between DC and 5 megahertz by careful adjustment of the gain of either channel while observing the displayed common-mode signal.

Deflection Factor. The overall deflection in the ADD position of the MODE switch when both VOLTS/DIV switches are set to the same position is the same as the deflection factor indicated by either VOLTS/DIV switch. The amplitude of an added mode display can be determined directly from the resultant CRT deflection multiplied by the deflection factor indicated by either VOLTS/DIV switch. However, if the CH 1 and CH 2 VOLTS/DIV switches are set to different deflection factors, resultant voltage is difficult to determine from the CRT display. In this case, the voltage amplitude of the resultant display can be determined accurately only if the amplitude of the signal applied to either channel is known.

Precautions. The following general precautions should be observed when using the ADD mode.

1. Do not exceed the input voltage rating of the Type 453.

2. Do not apply signals that exceed an equivalent of about 20 times the VOLTS/DIV switch setting. For example, with a VOLTS/DIV switch setting of .5, the voltage applied to that channel should not exceed about 10 volts. Larger voltages may distort the display.

3. Use vertical POSITION control settings which most nearly position the signal of each channel to mid-screen when viewed in either the CH 1 or CH 2 positions of the MODE switch. This insures the greatest dynamic range for ADD mode operation.

4. For similiar response from each channel, set both Input Coupling switches to the same position.

Trigger Source

INT. For most applications, the sweep can be triggered internally. In the INT position of the Triggering SOURCE switch, the trigger signal is obtained from the Vertical Deflection System. The TRIGGER switch provides further selection of the internal trigger signal; obtained from the Channel 1 signal in the CH 1 ONLY position, or from the displayed signal when in the NORM position. For single-trace displays of either channel, the NORM position provides the most convenient operation. However, for dual-trace displays special considerations must be made to provide the correct display. Set Dual-Trace Operation in this section for dual-trace triggering information.

LINE. The LINE position of the SOURCE switch connects a sample of the power-line frequency to the Trigger Generator circuit. Line triggering is useful when the input signal is time-related to the line frequency. It is also useful for providing a stable display of a line-frequency component in a complex waveform.

EXT. An external signal conected to the EXT TRIG INPUT connector can be used to trigger the sweep in the EXT position of the Triggering SOURCE switch. The external signal must be time-related to the displayed signal for a stable display. An external trigger signal can be used to provide a triggered display when the internal signal is too low in amplitude for correct triggering, or contains signal components on which it is not desired to trigger. It is also useful when signal tracing in amplifiers, phase-shift networks, wave-shaping circuits, etc. The signal from a single point in the circuit under test can be connected to the EXT TRIG INPUT connector through a signal probe or cable. The sweep is then triggered by the same signal at all times and allows amplitude, time relationship or waveshape changes of signals at various points in the circuit to be examined without resetting the trigger controls.

EXT ÷ 10. Operation in the EXT ÷ 10 position is the same as described for EXT except that the external triggering signal is attenuated 10 times. Attenuation of high-amplitude external triggering signals is desirable to broaden the range of the Triggering LEVEL control. When the COUPLING switch is set to LF REJ, attenuation is about 20:1.

Trigger Coupling

Four methods of coupling the trigger signal to the trigger circuits can be selected with the Triggering COUPLING switches. Each position permits selection or rejection of the frequency components of the trigger signal which can trigger the sweep.

AC. The AC position blocks the DC component of the trigger signal. Signals with low-frequency components below about 30 hertz are attenuated. In general, AC coupling can be used for most applications. However, if the trigger signal contains unwanted components or if the sweep is to be triggered at a low repetition rate or a DC level, one of the remaining COUPLING switch positions will provide a better display.

The triggering point in the AC position depends on the average voltage level of the trigger signal. If the trigger signals occur in a random fashion, the average voltage level will vary, causing the triggering point to vary also. This shift of the triggering point may be enough so it is impossible to maintain a stable display. In such cases, use DC coupling.

LF REJ. In the LF REJ position, DC is rejected and signals below about 30 kilohertz are attenuated. Therefore, the sweep will be triggered only by the higher-frequency components of the signal. This position is particularly useful for providing stable triggering if the trigger signal contains line-frequency components. Also, in the ALT position of the MODE switch, the LF REJ position provides the best display at high sweep rates when comparing two unrelated signals (TRIGGER switch set to NORM).

HF REJ. The HF REJ position passes all low-frequency signals between about 30 hertz and 50 kilohertz. DC is rejected and signals outside the given range are attenuated. When triggering from complex waveforms, this position is useful for providing stable display of low-frequency components.

DC. DC coupling can be used to provide stable triggering with low-frequency signals which would be attenuated in the AC position, or with low-repetition rate signals. The LEVEL control can be adjusted to provide triggering at the desired DC level on the waveform. When using internal triggering, the setting of the Channel 1 and 2 POSITION controls affects the DC trigger level.

DC trigger coupling should not be used in the ALT dual-trace mode if the TRIGGER switch is set to NORM. If used, the sweep will trigger on the DC level of one trace and then either lock out completely or free run on the other trace. Correct DC triggering for this mode can be obtained with the TRIGGER switch set to CH 1 ONLY.

Trigger Slope

The triggering SLOPE switch determines whether the trigger circuit responds on the positive-going or negative-going portion of the trigger signal. When the SLOPE switch is in the + (positive-going) position, the display starts with the positive-going portion of the waveform; in the — (negative-going) position, the display starts with the negative-going portion of the waveform (see Fig. 2-8). When several cycles of a signal appear in the display, the setting of the SLOPE switch is often unimportant. However, if only a certain portion of a cycle is to be displayed, correct setting of the SLOPE switch is important to provide a display which starts on the desired slope of the input signal.

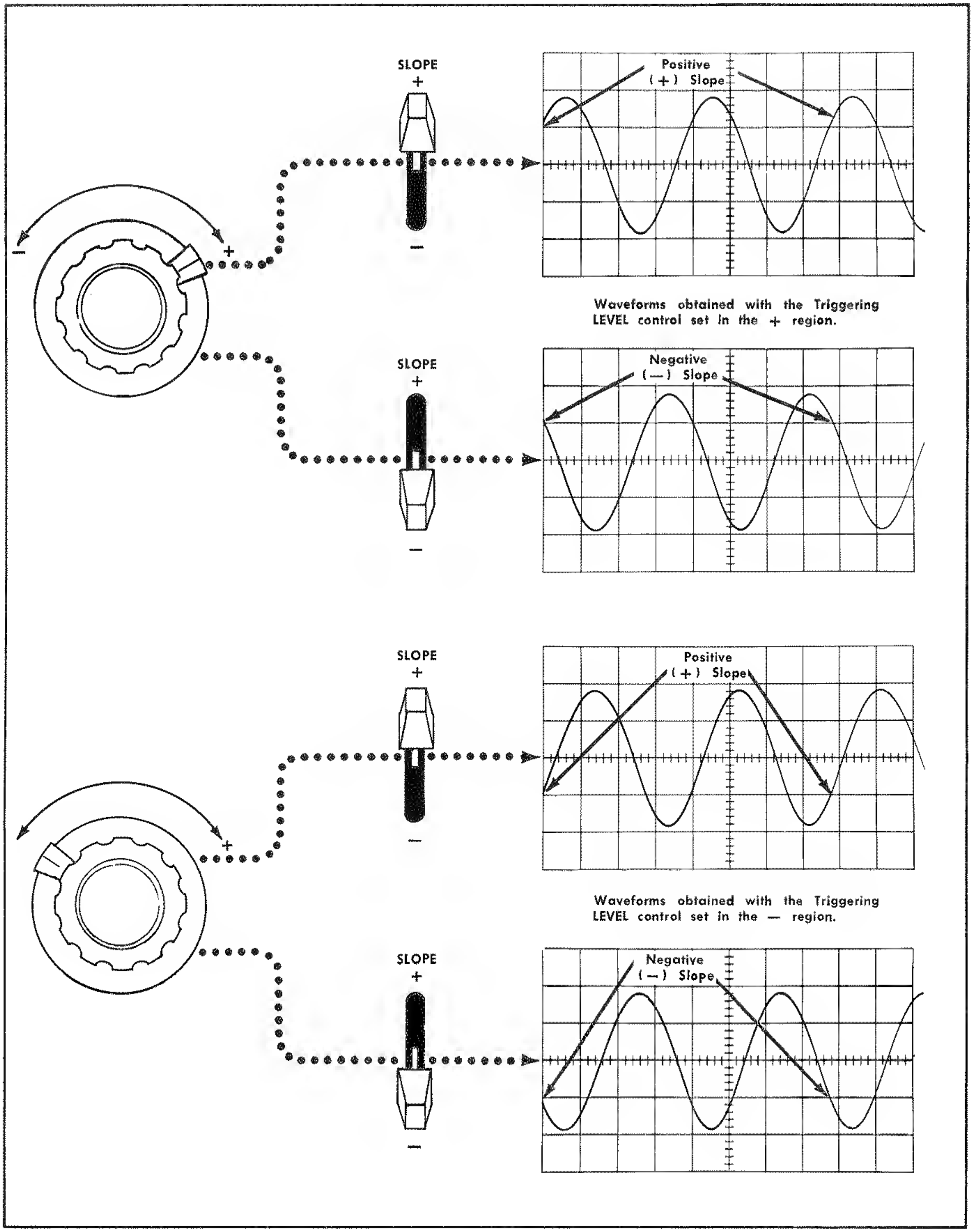


Fig. 2-8. Effects of Triggering LEVEL control and SLOPE switch.

Trigger Level

The Triggering LEVEL control determines the voltage level on the trigger signal at which the sweep is triggered. When the LEVEL control is set in the + region, the trigger circuit responds at a more positive point on the trigger signal. When the LEVEL control is set in the — region, the trigger circuit responds at a more negative point on the trigger signal. Fig. 2-8 illustrates this effect with different settings of the SLOPE switch.

To set the LEVEL control, first select the Triggering SOURCE, COUPLING and SLOPE. Then set the LEVEL control fully counterclockwise and rotate it clockwise until the display starts at the desired point.

High-Frequency Stability

The HF STAB control (A only) is used to provide a stable display of high-frequency signals. If a stable display cannot be obtained using the A LEVEL control (trigger signal must have adequate amplitude), adjust the HF STAB control for minimum horizontal jitter in the display. This control has little effect with low-frequency signals.

A Sweep Triggered Light

The A SWEEP TRIG'D light provides a convenient indication of the condition of the A Triggering circuit. If the A Triggering controls are correctly adjusted with an adequate trigger signal applied, the light is on. However, if the A LEVEL control is misadjusted, the A COUPLING or A SOURCE switches incorrectly set or the trigger signal too low in amplitude, the A SWEEP TRIG'D light will be off. This feature can be used as a general indication of correct triggering. It is particularly useful when setting up the trigger circuits when a trigger signal is available without a trace displayed on the CRT and it also indicates that the A sweep is correctly triggered when operating in the DELAYED SWEEP (B) mode.

A Sweep Mode

AUTO TRIG. The AUTO TRIG position of the A SWEEP MODE switch provides a stable display when the A LEVEL control is correctly set (see Trigger Level in this section) and a trigger signal is available. The A SWEEP TRIG'D light indicates when the A Sweep Generator is triggered.

When the trigger repetition rate is less than about 20 hertz, or in the absence of an adequate trigger signal, the A Sweep Generator free runs to produce a reference trace. When an adequate trigger signal is again applied, the free-running condition ends and the A Sweep Generator is triggered to produce a stable display (with correct A LEVEL control setting).

NORM TRIG. Operation in the NORM TRIG position when a trigger signal is applied is the same as in the AUTO TRIG position. However, when a trigger signal is not present, the A Sweep Generator remains off and there is no display. The A SWEEP TRIG'D light indicates when the A sweep is triggered. The NORM TRIG mode can be used to display signals with repetition rates below about 20 hertz. This mode provides an indication of an adequate trigger signal as well as the correctness of trigger control settings, since there is no display without proper triggering. Also, the A SWEEP TRIG'D light is off when the A sweep is not correctly triggered.

SINGLE SWEEP. When the signal to be displayed is not repetitive or varies in amplitude, shape or time, a conventional repetitive display may produce an unstable presentation. To avoid this, use the single-sweep feature of the Type 453. The SINGLE SWEEP mode can also be used to photograph a non-repetitive signal.

To use the SINGLE SWEEP mode, first make sure the trigger circuit will respond to the event to be displayed. Set the A SWEEP MODE switch to AUTO TRIG or NORM TRIG and obtain the best possible display in the normal manner (for random signals set the trigger circuit to trigger on a signal which is approximately the same amplitude and frequency as the random signal). Then, set the A SWEEP MODE switch to SINGLE SWEEP and press the RESET button. When the RESET button is pushed, the next trigger pulse initiates the sweep and a single trace will be presented on the screen. After this sweep is complete, the A Sweep Generator is "locked out" until reset. The RESET light located inside the RESET button lights when the A Sweep Generator circuit has been reset and is ready to produce a sweep; it goes out after the sweep is complete. To prepare the circuit for another single-sweep display, press the RESET button again.

Selecting Sweep Rate

The A AND B TIME/DIV switches select calibrated sweep rates for the Sweep Generators. The A and B VARIABLE controls provide continuously variable sweep rates between the settings of the TIME/DIV switches. Whenever the UNCAL A OR B light is on, the sweep rate of either A or B Sweep Generator, or both, is uncalibrated. The light is off when the A VARIABLE (front panel) and B TIME/DIV VARIABLE (side panel) controls are both set to the CAL position.

The sweep rate of the A Sweep Generator is bracketed by the two black lines on the clear plastic flange of the TIME/DIV switch (see Fig. 2-9). The B Sweep Generator sweep rate is indicated by the dot on the DELAYED SWEEP knob. When the dot on the outer knob is set to the same position as the lines on the inner knob, the two knobs lock together and the sweep rate of both Sweep Generators is changed at the same time. However, when the DELAYED SWEEP knob is pulled outward, the clear plastic flange is disengaged and only the B Sweep Generator sweep rate is changed. This allows changing the delayed sweep rate wihout changing the delay time determined by the A Sweep Generator.

When making time measurements from the graticule, the area between the first-division and ninth-division vertical lines provides the most linear time measurement (see Fig. 2-10). Therefore, the first and last division of the display should not be used for making accurate time measurements. Position the start of the timing area to the first-division vertical line and set the TIME/DIV switch so the end of the timing area falls between the first- and ninth-division vertical lines.

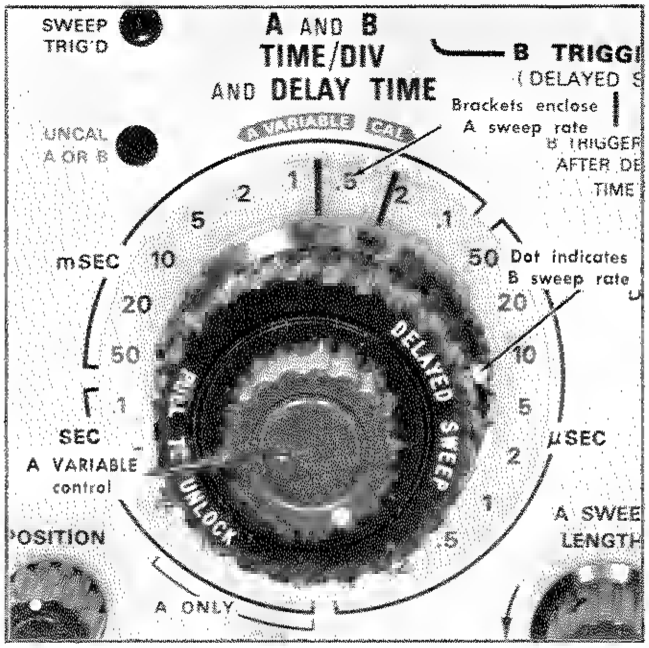


Fig. 2-9. A AND B TIME/DIV switch.

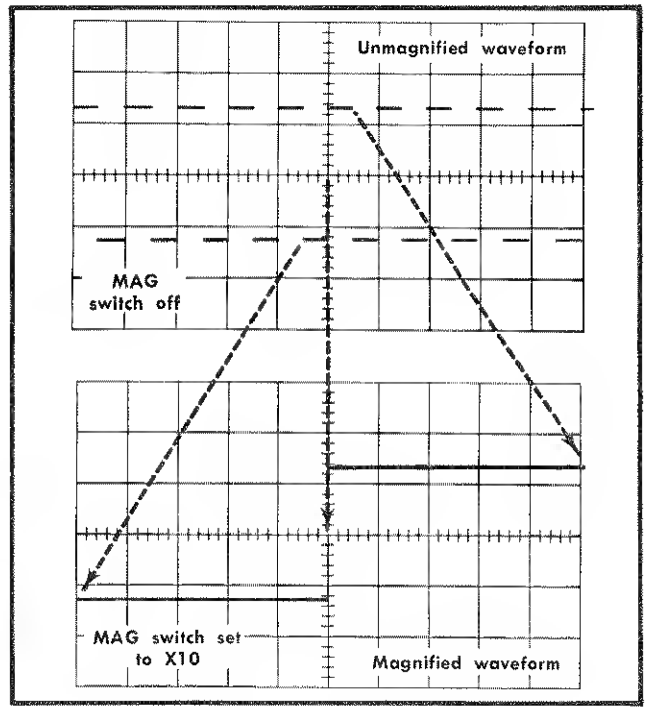


Fig. 2-11. Operation of sweep magnifier.

Sweep Magnification

The sweep magnifier expands the sweep ten times. The center division of the unmagnified display is the portion visible on the screen in magnified form (see Fig. 2-11). Equivalent length of the magnified sweep is about 100 divisions; any 10 division portion may be viewed by adjusting the horizontal POSITION control to bring the desired portion onto the viewing area. The FINE position control is particularly useful when the magnifier is on, as it provides positioning in small increments for more precise control.

To use the magnified sweep, first move the portion of the display which is to be expanded to the center of the graticule. Then set the MAG switch to ×10. The FINE position control can be adjusted to position the magnified display as desired. The light located below the MAG switch is on whenever the magnifier is on.

When the MAG switch is set to ×10, the sweep rate is determined by dividing the TIME/DIV switch setting by 10. For example, if the TIME/DIV switch is set to .5 µs, the magnified sweep rate is 0.05 microsecond/division. The magnified sweep rate must be used for all time measurements when the MAG switch is set to ×10. The magnified sweep rate is calibrated when the UNCAL A OR B light is off.

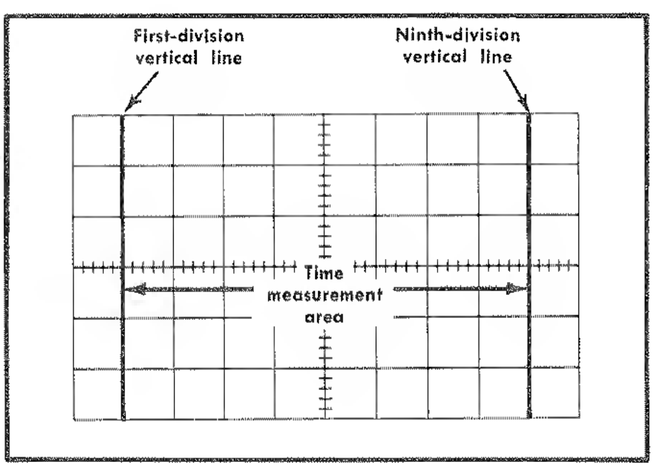


Fig. 2-10. Area of graticule used for accurate time measurements.

Delayed Sweep (B)

The delayed sweep (B sweep) is operable in the A INTEN DURING B and DELAYED SWEEP (B) positions of the HORIZ DISPLAY switch. The A sweep rate along with the DELAY-TIME MULTIPLIER dial setting determines the time that the B sweep is delayed. Sweep rate of the delayed portion is determined by the B TIME/DIV (DELAYED SWEEP) switch setting.

In the A INTEN DURING B position, the display will appear similar to Fig. 2-12A. The amount of delay time between the start of A sweep and the intensified portion is determined by the setting of the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial.

For example, the delay indicated by the DELAY-TIME MULTIPLIER dial setting shown in Fig. 2-13 is 3.55; this corresponds to 3.55 CRT divisions of A sweep. This reading multiplied by the setting of the A TIME/DIV switch gives the calibrated delay time before the start of the B sweep (see B Sweep Mode which follows). The intensified portion of the display is produced by the B sweep. The length of

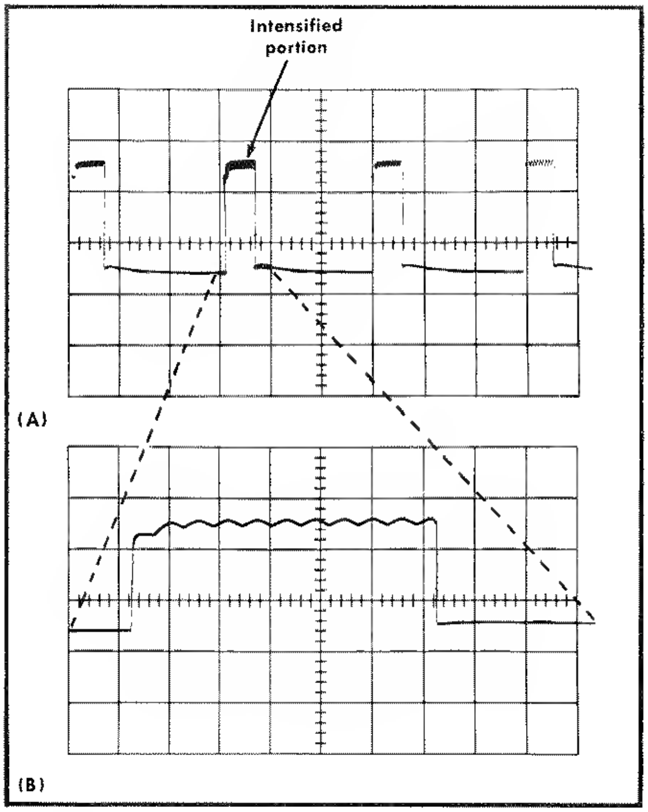


Fig. 2-12. (A) A INTEN DURING B display (DELAY-TIME MULTIPLIER, 2.95; A TIME/DIV, .5 ms; B TIME/DIV, 50 μs), (B) DELAYED SWEEP (B) display.

this portion is about 10 times the setting of the B TIME/DIV switch.

When the HORIZ DISPLAY switch is set to DELAYED SWEEP (B), only the intensified portion as viewed in the A INTEN DURING B position is displayed on the screen at the sweep rate indicated by the B TIME/DIV switch (see Fig. 2-12B).

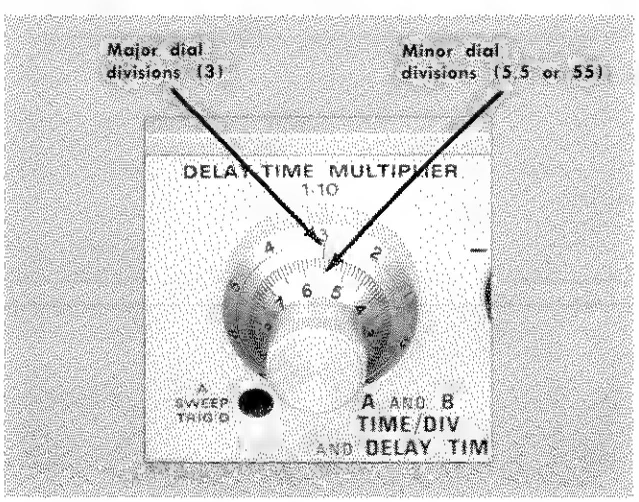


Fig. 2-13. DELAY-TIME MULTIPLIER dial. Reading shown: 3.55.

B SWEEP MODE. The B SWEEP MODE switch provides two modes of delayed sweep operation. Fig. 2-14 illustrates the difference between these two modes. In the B STARTS AFTER DELAY TIME position, the B sweep is presented immediately after the delay time (see Fig. 2-14A). The B sweep is triggered at a selected point on A sweep to provide the delay time (B sweep essentially free running). Since the delay time is the same for each sweep, the display appears stable. In the TRIGGERABLE AFTER DELAY TIME position, the B sweep operates only when it is triggered (by Trigger Circuits) after the selected delay time (see Fig. 2-14B). The B Triggring controls operate as described in this section.

Delayed Sweep Operation. To obtain a delayed sweep display use the following procedure.

1. Obtain a stable display with the HORIZ DISPLAY switch set to A.

2. Set the HORIZ DISPLAY switch to A INTEN DURING B.

3. Set the B SWEEP MODE switch to the desired setting. If TRIGGERABLE AFTER DELAY TIME is selected, correct B Triggering is also necessary.

4. Set the delay time with the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial.

5. Pull the DELAYED SWEEP (B TIME/DIV) knob out and set to the desired sweep rate.

6. If the TRIGGERABLE AFTER DELAY TIME position is used, check the display for an intensified portion. Absence of the intensified zone indicates that B sweep is not correctly triggered.

7. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). The intensified zone shown in the A INTEN DURING B position is now displayed at the sweep rate selected by the B TIME/DIV switch.

Several examples using the delayed sweep feature are given under Basic Applications in this section.

A Sweep Length. The A SWEEP LENGTH control is most useful when used with delayed sweep. As the control is rotated counterclockwise from the FULL position, the length of the A sweep decreases (sweep rate remains constant) until it is about four divisions long in the counterclockwise position (not in B ENDS A detent). The B ENDS A position produces a display which ends immediately following B sweep if the B sweep ends before the normal end of A sweep. The A SWEEP LENGTH control is used to increase the repetition rate of delayed sweep displays.

To use the A SWEEP LENGTH control, set the HORIZ DISPLAY switch to A INTEN DURING B and set the delay time and delayed sweep rate in the normal manner. Turn the A SWEEP LENGTH control counterclockwise until the sweep ends immediately following the intensified portion on the display. Now set the HORIZ DISPLAY switch to DELAYED SWEEP (B). This method provides the maximum repetition rate for a given delayed sweep display. In the B ENDS A position, the maximum delayed sweep repetition rate is maintained automatically.

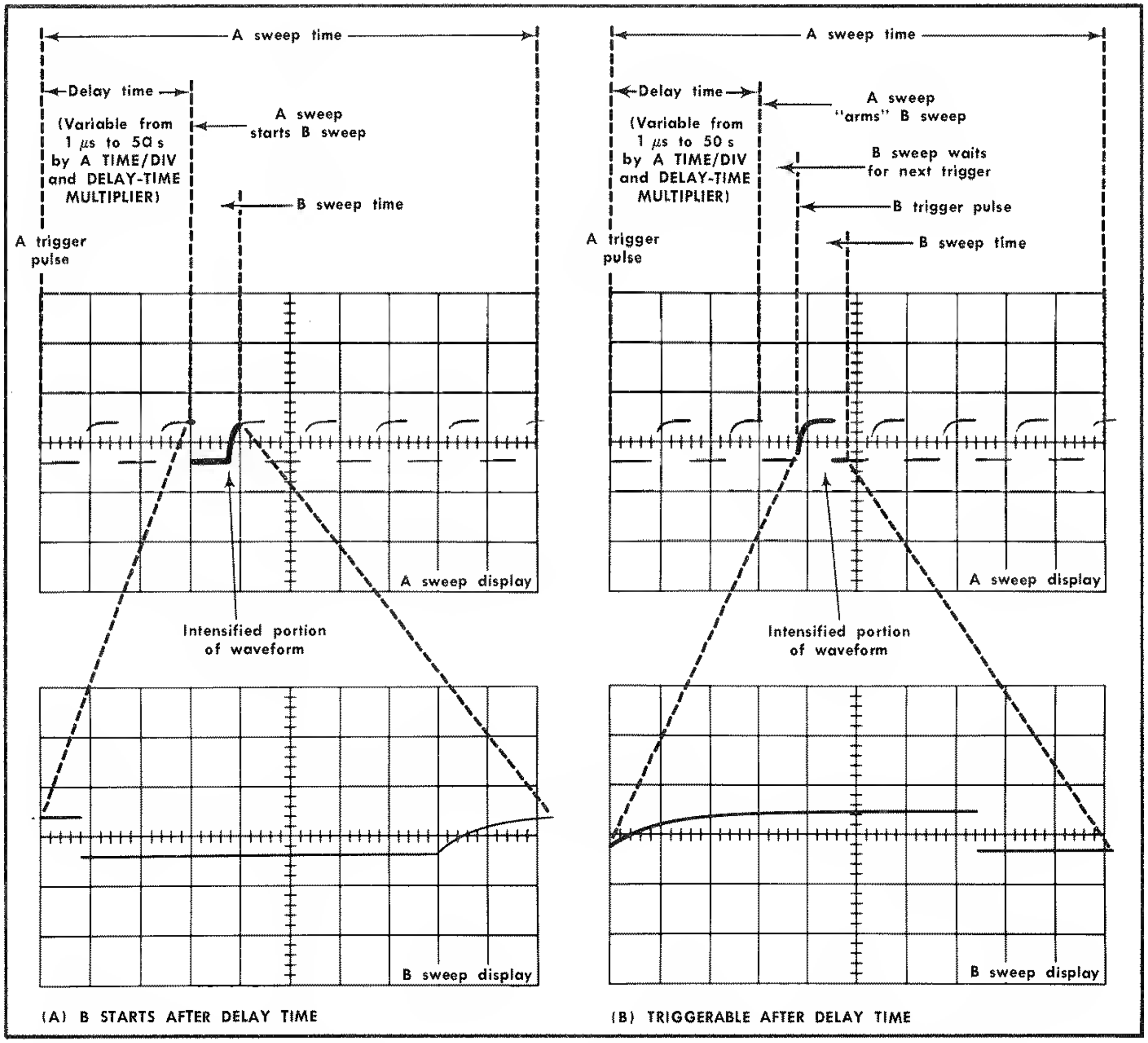


Fig. 2-14. Comparison of the delayed-sweep modes. (A) B STARTS AFTER DELAY TIME, (B) TRIGGERABLE AFTER DELAY TIME. In each display the B sweep is delayed a selected amount of time by A sweep.

NOTE

Jitter can be introduced into the display and incorrect displays produced through the wrong usage of the A SWEEP LENGTH control. When using this control first obtain the best possible display in the FULL position. Then, set the control for the desired A sweep length. If jitter is evident in the display, readjust the Triggering controls or change the A SWEEP LENGTH control to a position that does not cause jitter.

External Horizontal Deflection

In some applications, it is desirable to display one signal versus another (X-Y) rather than against time (internal sweep). The EXT HORIZ position of the HORIZ DISPLAY switch provides a means for applying an external signal to the horizontal amplifier for this type of display.

Two modes of external horizontal operation are provided. When the TRIGGER switch is set to CH 1 ONLY, the B SOURCE switch to INT and the B COUPLING switch to DC, the horizontal deflection is provided by a signal applied to the Channel 1 INPUT connector. The CH 1 VOLTS/DIV switch setting indicates the calibrated horizontal deflection factor (Channel 1 VARIABLE control in-operative). Center the horizontal POSITION control and use the Channel 1 POSITION control for horizontal positioning.

In the EXT and EXT ÷ 10 positions of the B SOURCE switch, external horizontal deflection is provided by a signal

applied to the EXT HORIZ input connector (B EXT TRIG INPUT). The signal coupling provided by the B COUPLING switch can be used to select or reject components of the external horizontal signal (all components of external horizontal signal accepted in DC position). Using this mode of operation, the horizontal deflection factor is uncalibrated. External horizontal deflection factor is about 270 millivolts/division in the EXT position of the B SOURCE switch and about 2.7 volts/division in the EXT ÷ 10 position.

A and B Gate

The A and B Gate output connectors (on side panel) provide a rectangular output pulse which is coincident with the sweep time of the respective sweep generator. This rectangular pulse is about +12 volts in amplitude (into high-impedance loads) with pulse duration the same as the respective sweep.

Intensity Modulation

Intensity (Z-axis) modulation can be used to relate a third item of electrical phenomena to the vertical (Y-axis) and the horizontal (X-axis) coordinates without changing the wave shape. The Z-axis modulating signal applied to the CRT circuit changes the intensity of the displayed waveform to provide this display. "Gray scale" intensity modulation can be obtained by applying signals which do not completely blank the display. Large amplitude signals of the correct polarity will completely blank the display; the sharpest display is provided by signals with a fast rise and fall. The voltage amplitude required for visible trace modulation depends upon the setting of the INTENSITY control. At normal intensity level, a five-volt peak-to-peak signal produces a visible change in brightness. When the Z AXIS INPUT is not in use, keep the ground strap in place to prevent changes in trace intensity due to extraneous noise.

Time markers applied to the Z AXIS INPUT connector provide a direct time reference on the display. With uncalibrated horizontal sweep or external horizontal mode operation, the time markers provide a means of reading time directly from the display. However, if the markers are not time-related to the displayed waveform, a single-sweep display should be used (for internal sweep only) to provide a stable display.

Calibrator

The one-kilohertz square-wave Calibrator of the Type 453 provides a convenient signal source for checking basic vertical gain and sweep timing. However, to provide maximum measurement acuracy, the adjustment procedure given in the Calibration section of this manual should be used. The Calibrator output signal is also very useful for adjusting probe compensation as described in the probe instruction manual. In addition, the calibrator con be used as a convenient signal source for application to external equipment.

Voltage. The Calibrator provides accurate peak-to-peak square-wave voltages of 0.1 and 1 volt into a high impedance load. Voltage range is selected by the CALIBRATOR switch on the side panel. Output resistance is about 200 ohms in the 1 V position and about 20 ohms in the 0.1 V position. The actual voltage across an external load resistor can be calculated in the same manner as with any series resistor combination (necessary only if the load resistance is less than about 50 kilohms).

Current. The current loop, located on the side panel, provides a five milliampere peak-to-peak square-wave current which can be used to check and calibrate current-measuring probe systems. This current signal is obtained by clipping the probe around the current loop. Current is constant through the loop in either position of the CALIBRATOR switch. The arrow above the PROBE LOOP indicates conventional current flow; i.e., from + to —.

Frequency. The Calibrator circuit uses frequency-stable components to mointain accurate frequency and constant duty cycle. Thus the Calibrator can be used for checking the basic sweep timing of the horizantal system.

Wave shape. The square-wave output signal of the Calibrator can be used as a reference wave shape when checking or adjusting the compensation of passive, high-resistance probes. Since the square-wave output from the Calibrator has a flat top, any distortion in the displayed waveform is due to the probe compensation.

BASIC APPLICATIONS

General

The following information describes the procedure and technique for making basic measurements with a Type 453 Oscilloscope. These applications are not described in detail since each application must be adapted to the requirements of the individual measurements. Familiarity with the Type 453 will permit these basic techniques to be applied to a wide variety of uses.

Peak-to-Peak Voltage Measurements—AC

To make a peak-to-peak voltage measurement, use the following procedure:

1. Connect the signal to either INPUT connector.

2. Set the MODE switch to display the channel used.

3. Set the VOLTS/DIV switch to display about five divisions of the waveform.

4. Set the Input Coupling switch to AC.

NOTE

For low-frequency signals below about 16 hertz, use the DC position.

5. Set the A Triggering controls to obtain a stable display. Set the TIME/DIV switch to a position that displays several cycles of the waveform.

6. Turn the vertical POSITION control so the lower portion of the waveform coincides with one of the graticule lines below the center horizontal line, and the top of the waveform is on the viewing area. Move the display with the horizontal POSITION control so one of the upper peaks lies near the center vertical line (see Fig. 2-15).

7. Measure the divisions of vertical deflection from peak to peak. Make sure the VARIABLE VOLTS/DIV control is in the CAL position.

NOTE

This technique may also be used to make measurements between two points on the waveform rather than peak to peak.

8. Multiply the distance measured in step 7 by the VOLTS/DIV switch setting. Also include the attenuation factor of the probe, if any.

Example. Assume a peak-to-peak vertical deflection of 4.6 divisions (see Fig. 2-15) using a 10× attenuator probe and a VOLTS/DIV switch setting of .5.

Using the formula:

$$\text{Volts Peak to Peak} = \begin{matrix}\text{vertical}\\\text{deflection}\\\text{(divisions)}\end{matrix} \times \begin{matrix}\text{VOLTS/DIV}\\\text{setting}\end{matrix} \times \begin{matrix}\text{probe}\\\text{attenuation}\\\text{factor}\end{matrix}$$

Substituting the given values:

Volts Peak to Peak $= 4.6 \times 0.5\,V \times 10$

The peak-to-peak voltage is 23 volts.

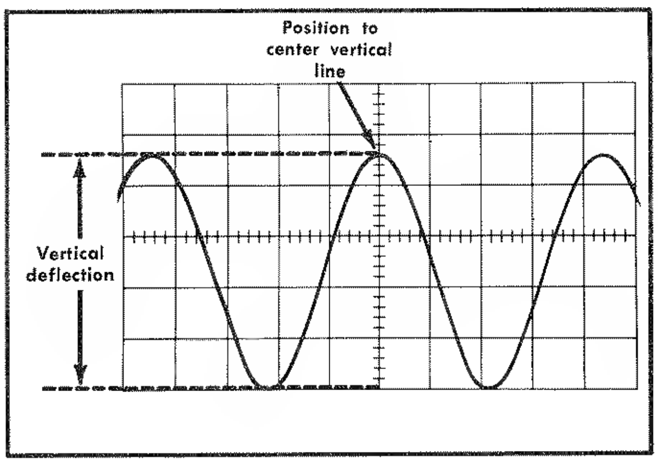


Fig. 2-15. Measuring peak-to-peak voltage of a waveform.

Instantaneous Voltage Measurements—DC

To measure the DC level at a given point on a waveform, use the following procedure:

1. Connect the signal to either INPUT connector.

2. Set the MODE switch to display the channel used.

3. Set the VOLTS/DIV switch to display about five divisions of the waveform.

4. Set the Input Coupling switch to GND.

5. Set the A SWEEP MODE switch to AUTO TRIG.

6. Position the trace to the bottom line of the graticule or other reference line. If the voltage is negative with respect to ground, position the trace to the top line of the graticule. Do not move the vertical POSITION control after this reference line has been esablished.

NOTE

To measure a voltage level with respect to a voltage rather than ground, make the following changes in step 6. Set the Input Coupling switch to DC and apply the reference voltage to the INPUT connector. Then position the trace to the reference line.

7. Set the Input Coupling switch to DC. The ground reference line can be checked at any time by switching to the GND position (except when using a DC reference voltage).

8. Set the A Triggering controls to obtain a stable display. Set the TIME/DIV switch to a setting that displays several cycles of the signal.

9. Measure the distance in divisions between the reference line and the point on the waveform at which the DC level is to be measured. For example, in Fig. 2-16 the measurement is made between the reference line and point A.

10. Establish the polarity of the signal. If the waveform is above the reference line, the voltage is positive; below the line, negative (when the INVERT switch is pushed in if using Channel 2).

11. Multiply the distance measured in step 9 by the VOLTS/DIV switch setting. Include the attenuation factor of the probe, if any.

Example. Assume that the vertical distance measured is 4.6 divisions (see Fig. 2-16), the waveform is above the reference line, using a 10× attenuator probe and a VOLTS/DIV setting of 2.

Using the formula:

$$\begin{matrix}\text{Instantaneous}\\\text{Voltage}\end{matrix} = \begin{matrix}\text{vertical}\\\text{distance}\\\text{(divisions)}\end{matrix} \times \text{polarity} \times \begin{matrix}\text{VOLTS/DIV}\\\text{setting}\end{matrix} \times \begin{matrix}\text{probe}\\\text{attenuation}\\\text{factor}\end{matrix}$$

Substituting the given values:

$$\begin{matrix}\text{Instantaneous}\\\text{Voltage}\end{matrix} = 4.6 \times +1 \times 2\,V \times 10$$

The instantaneous voltage is +92 volts.

Voltage Comparison Measurements

In some applications it may be necessary to establish a set of deflection factors other than those indicated by the VOLTS/DIV switch. This is useful for comparing signals to a reference voltage amplitude. To establish a new set of deflection factors based upon a specific reference amplitude, proceed as follows:

1. Apply the reference signal of known amplitude to either INPUT conector. Set the MODE switch to display the channel used. Using the VOLTS/DIV switch and the VARIABLE control, adjust the display for an exact number of divisions. Do not move the VARIABLE VOLTS/DIV control after obtaining the desired deflection.

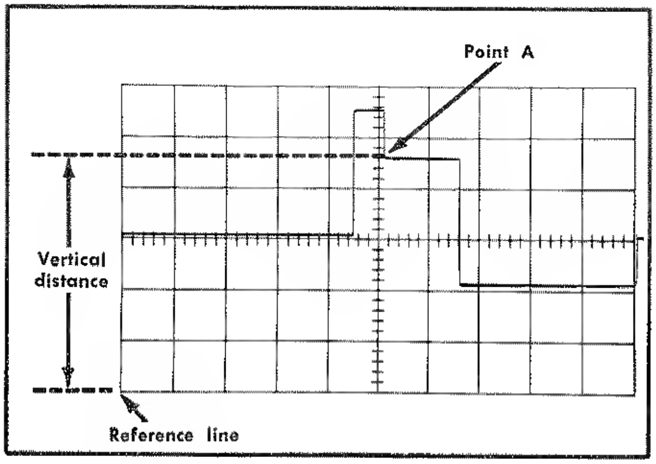


Fig. 2-16. Measuring instantaneous DC voltage with respect to a reference.

2. Divide the amplitude of the reference signal (volts) by the product of the deflection in divisions (established in step 1) and the VOLTS/DIV switch setting. This is the Deflection Conversion Factor.

$$\text{Deflection Conversion Factor} = \frac{\text{reference signal amplitude (volts)}}{\text{deflection (divisions)} \times \text{VOLTS/DIV setting}}$$

3. To establish an Adjusted Deflection Factor at any setting of the VOLTS/DIV switch, multiply the VOLTS/DIV switch setting by the Deflection Conversion Factor established in step 2.

$$\text{Adjusted Deflection Factor} = \text{VOLTS/DIV setting} \times \text{Deflection Conversion Factor}$$

This Adjusted Deflection Factor applies only to the channel used and is correct only if the VARIABLE VOLTS/DIV control is not moved from the position set in step 1.

4. To determine the peak to peak amplitude of a signal compared to a reference, disconnect the reference and apply the signal to the INPUT connector.

5. Set the VOLTS/DIV switch to a setting that will provide sufficient deflection to make the measurement. Do not readjust the VARIABLE VOLTS/DIV control.

6. Measure the vertical deflection in divisions and determine the amplitude by the following formula:

$$\text{Signal Amplitude} = \text{Adjusted Deflection Factor} \times \text{deflection (divisions)}$$

Example. Assume a reference signal amplitude of 30 volts, a VOLTS/DIV setting of 5 and a deflection of 4 divisions. Substituting these values in the Deflection Conversion Factor formula (step 2):

$$\text{Deflection Conversion Factor} = \frac{30\text{ V}}{4 \times 5\text{ V}} = 1.5$$

Then, with a VOLTS/DIV switch setting of 10, the Adjusted Deflection Factor (step 3) is:

$$\text{Adjusted Deflection Factor} = 10\text{ V} \times 1.5 = 15\text{ volts/division}$$

To determine the peak-to-peak amplitude of an applied signal which produces a vertical deflection of 5 divisions, use the Signal Amplitude formula (step 6):

$$\text{Signal Amplitude} = 15\text{ V} \times 5 = 75\text{ volts}$$

Time-Duration Measurements

To measure time between two points on a waveform, use the following procedure.

1. Connect the signal to either INPUT connector.

2. Set the MODE switch to display the channel used.

3. Set the VOLTS/DIV switch to display about five divisions of the waveform.

4. Set the A Triggering controls to obtain a stable display.

5. Set the TIME/DIV switch to the fastest sweep rate that displays less than eight divisions between the time measurement points (see Fig. 2-17). (See the topic entitled Selecting Sweep Rate in this section concerning non-linearity of first and last divisions of display.)

6. Adjust the vertical POSITION control to move the points between which the time measurement is made to the center horizontal line.

7. Adjust the horizontal POSITION control to center the display within the center eight divisions of the graticule.

8. Measure the horizontal distance between the time measurement points. Be sure the A VARIABLE control is set to CAL.

9. Multiply the distance measured in step 8 by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 10.

Example. Assume that the distance between the time measurement points is 5 divisions (see Fig. 2-17) and the TIME/DIV switch is set to .1 ms with the magnifier off.

Using the formula:

$$\text{Time Duration} = \frac{\text{horizontal distance (divisions)} \times \text{TIME/DIV setting}}{\text{magnification}}$$

Substituting the given values:

$$\text{Time Duration} = \frac{5 \times 0.1\text{ ms}}{1}$$

The time duration is 0.5 milliseconds.

Frequency Measurements

The time measurement technique can also be used to measure the frequency of a signal. The frequency of a periodically-recurrent signal is the reciprocal of the time duration of one cycle.

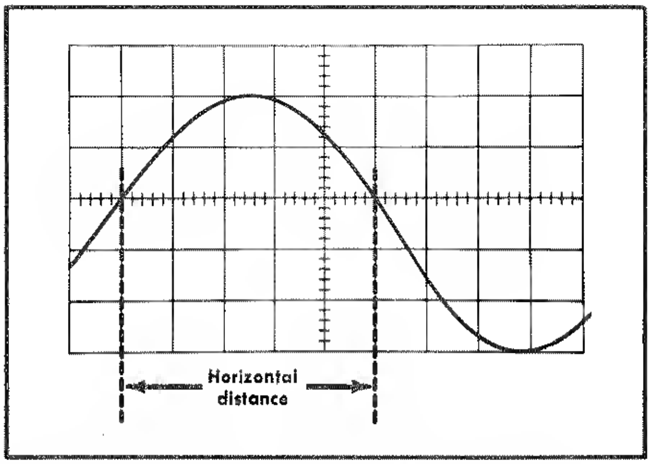


Fig. 2-17. Measuring the time duration between points on a waveform.

1. Measure the time duration of one cycle of the waveform as described in the previous application.

2. Take the reciprocal of the time duration to determine the frequency.

Example. The frequency of the signal shown in Fig. 2-17 which has a time duration of 0.5 milliseconds is:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{0.5\text{ ms}} = 2\text{ kHz}$$

Risetime Measurements

Risetime measurements employ basically the same techniques as time-duration measurements. The main difference is the points between which the measurement is made. The following procedure gives the basic method of measuring risetime between the 10% and 90% points of the waveform. Falltime can be measured in the same manner on the trailing edge of the waveform.

1. Connect the signal to either INPUT connector.

2. Set the MODE switch to display the channel used.

3. Set the VOLTS/DIV switch and the VARIA8LE control to produce a display an exact number of divisions in amplitude.

4. Center the display about the center horizontal line.

5. Set the A Triggering controls to obtain a stable display.

6. Set the TIME/DIV switch to the fastest sweep rate that displays less than eight divisions between the 10% and 90% points on the waveform.

7. Determine the 10% and 90% points on the rising portion of the waveform. The figures given in Table 2-2 are for the points 10% up from the start of the rising portion and 10% down from the top of the rising portion (90% point).

8. Adjust the horizontal POSITION control to move the 10% point of the waveform to the first graticule line. For

Vertical display (divisions)	10% and 90% points	Divisions vertically between 10% & 90% points
4	0.4 and 3.6 divisions	3.2
5	0.5 and 3.5 divisions	4.0
6	0.6 and 3.4 divisions	4.8

example, with a five-division display as shown in Fig. 2-18, the 10% point is 0.5 division up from the start of the rising partian.

9. Measure the harizontal distance between the 10% and 90% points. 8e sure the A VARIABLE cantral is set ta CAL.

10. Multiply the distance measured in step 8 by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 10.

Example. Assume that the horizontal distance between the 10% and 90% points is four divisions (see Fig. 2-18) and the TIME/DIV switch is set to 1 μs with the MAG switch set to $\times$10.

Applying the time duration formula to risetime:

$$\begin{array}{c}\text{Risetime} \\ \text{(Time Duration)}\end{array} = \frac{\begin{array}{c}\text{horizontal} \\ \text{distance} \\ \text{(divisions)}\end{array} \times \begin{array}{c}\text{TIME/DIV} \\ \text{setting}\end{array}}{\text{magnification}}$$

Substituting the given values:

$$\text{Risetime} = \frac{4 \times 1\ \mu\text{s}}{10}$$

The risetime is 0.4 microsecond.

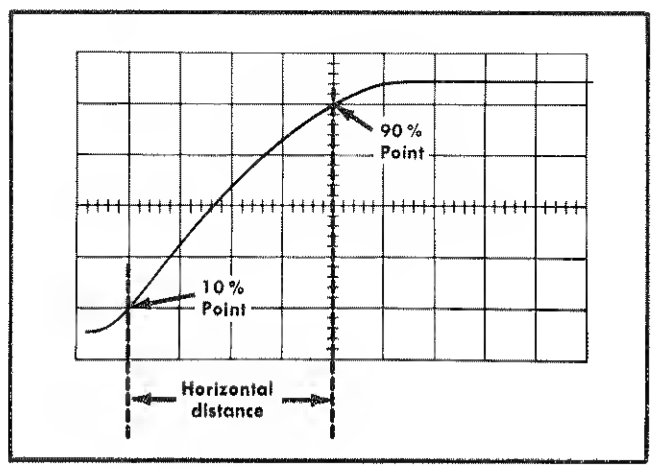


Fig. 2-18. Measuring risetime.

Time-Difference Measurements

The calibrated sweep rate and dual-trace features of the Type 453 allow measurement of time difference between two separate events. To measure time difference, use the following procedure.

1. Set the Input Coupling switches to the desired coupling positions.

2. Set the MODE switch to either CHOP or ALT. In general, CHOP is more suitable for low-frequency signals and the ALT position is more suitable for high-frequency signals. More information on determining the mode is given under Dual-Trace Operation in this section.

3. Set the TRIGGER switch to CH 1 ONLY.

4. Connect the reference signal to Channel 1 INPUT and the comparison signal to Channel 2 INPUT. The reference signal should precede the comparison signal in time. Use coaxial cables or probes which have equal time delay to connect the signals to the INPUT connectors.

5. If the signals are of opposite polarity, pull out the INVERT switch to invert the Channel 2 display (signal may be of opposite polarity due to 180° time difference; if so, take into account in final calculation).

6. Set the VOLTS/DIV switches to produce four-or five-division displays.

7. Set the A LEVEL control for a stable display.

8. If possible, set the TIME/DIV switch for a sweep rate which shows three or more divisions between the two waveforms.

9. Adjust the vertical POSITION controls to center each waveform (or the points on the display between which the measurement is made) in relation to the center horizontal line.

10. Adjust the horizontal POSITION control so the Channel 1 (reference) waveform crosses the center horizontal line at a vertical graticule line.

11. Measure the horizontal difference between the Channel 1 waveform and the Channel 2 waveform (see Fig. 2-19).

12. Multiply the measured difference by the setting of the TIME/DIV switch. If sweep magnification is used, divide this answer by 10.

Example. Assume that the TIME/DIV switch is set to 50 μs, the MAG switch to $\times$10 and the horizontal difference between waveforms is 4.5 divisions (see Fig. 2-19).

Using the formula:

$$\text{Time Delay} = \frac{\begin{matrix}\text{TIME/DIV} \\ \text{setting}\end{matrix} \times \begin{matrix}\text{horizontal} \\ \text{difference} \\ \text{(divisions)}\end{matrix}}{\text{magnification}}$$

Substituting the given values:

$$\text{Time Delay} = \frac{50\ \mu\text{s} \times 4.5}{10}$$

The time delay is 22.5 microseconds.

Delayed Sweep Time Measurements

The delayed sweep mode can be used to make accurate time measurements. The following measurement determines the time difference between two pulses displayed on the same trace. This application may also be used to measure

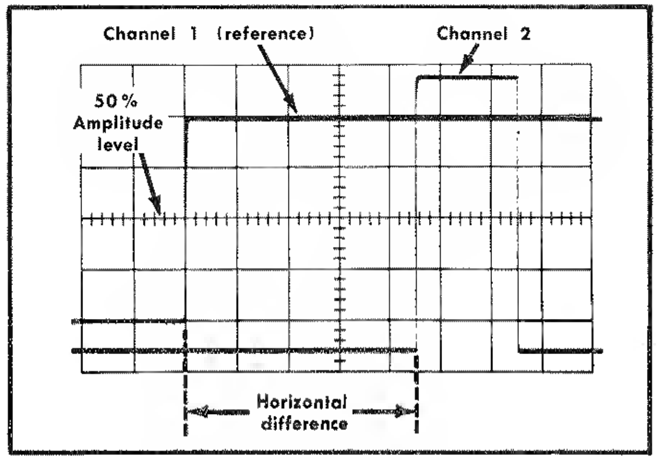


Fig. 2-19. Measuring time difference between two pulses.

time difference from two different sources (dual-trace) or to measure time duration of a single pulse. See Section 1 for measurement accuracy.

1. Connect the signal to either INPUT connector. Set the MODE switch to display the channel used.

2. Set the VOLTS/DIV switch to produce a display about four divisions in amplitude.

3. Adjust the A Triggering controls for a stable display.

4. If possible, set the A TIME/DIV switch to a sweep rate which displays about eight divisions between the pulses.

5. Set the HORIZ DISPLAY switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.

6. Set the B TIME/DIV switch to a setting 1/100 of the A TIME/DIV sweep rate. This produces an intensified portion about 0.1 division in length.

NOTE

Do not change the A LEVEL control setting or the horizontal POSITION control setting in the following steps as the measurement accuracy will be affected.

7. Turn the DELAY-TIME MULTIPLIER dial to move the intensified portion to the first pulse.

8. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B).

9. Adjust the DELAY-TIME MULTIPLIER dial to move the pulse (or the rising portion) to the center vertical line. Note the setting of the DELAY-TIME MULTIPLIER dial.

10. Turn the DELAY-TIME MULTIPLIER dial clockwise until the second pulse is positioned to this same point (if several pulses are displayed, return to the A INTEN DURING B position to locate the correct pulse). Again note the dial setting.

11. Subtract the first dial setting from the second and multiply by the delay time shown by the A TIME/DIV switch. This is the time interval between the pulses.

Example. Assume the first dial setting is 1.31 and the second dial setting is 8.81 with the TIME/DIV switch set to 0.2 microsecond (see Fig. 2-20).

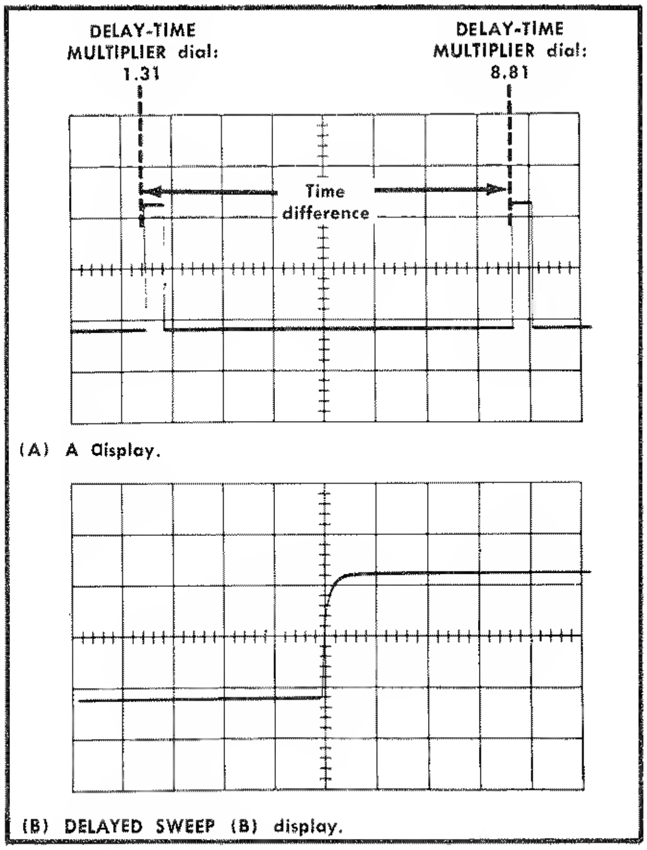
Using the formula:

$$\text{Time Difference (delayed sweep)} = [\text{second dial setting} - \text{first dial setting}] \times \text{delay time (A TIME/DIV setting)}$$

Substituting the given values:

$$\text{Time Difference} = [8.81 - 1.31] \times 0.2\,\mu s$$

The time difference is 1.5 microseconds.



(A) A display.

(B) DELAYED SWEEP (B) display.

Fig. 2-20. Measuring time difference using delayed sweep.

Delayed Sweep Magnification

The delayed sweep feature of the Type 453 can be used to provide higher apparent magnification than is provided by the MAG switch. The sweep rate of the DELAYED SWEEP (B sweep) is not actually increased; the apparent magnification is the result of delaying the B sweep an amount of time selected by the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial before the display is presented at the sweep rate selected by the B TIME/DIV switch. The following methods uses the B STARTS AFTER DELAY TIME position to allow the delayed portion to be positioned with the DELAY-TIME MULTIPLIER dial. If there is too much jitter in the delayed display, use the Triggered Delayed Sweep Magnification procedure.

1. Connect the signal to either INPUT connector. Set the MODE switch to display the channel used.

2. Set the VOLTS/DIV switch to produce a display about 4 divisions in amplitude.

3. Adjust the A Triggering controls for a stable display.

4. Set the A TIME/DIV switch to a sweep rate which displays the complete waveform.

5. Set the HORIZ DISPLAY switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.

6. Position the start of the intensified portion with the DELAY-TIME MULTIPLIER dial to the part of the display to be magnified.

7. Set the B TIME/DIV switch to a setting which intensifies the full portion to be magnified. The start of the intensified trace will remain as positioned above.

8. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B).

9. Time measurements can be made from the display in the conventional manner. Sweep rate is determined by the setting of the B TIME/DIV switch.

10. The apparent sweep magnification can be calculated by dividing the A TIME/DIV switch setting by the B TIME/DIV switch setting.

Example: The apparent magnification of the display shown in Fig. 2-21 with an A TIME/DIV switch setting of .1 ms and a B TIME/DIV switch setting of 1 μs is:

$$\text{Apparent Magnification (delayed sweep)} = \frac{\text{A TIME/DIV setting}}{\text{B TIME/DIV setting}}$$

Substituting the given values:

$$\text{Apparent Magnification} = \frac{1 \times 10^{-4}}{1 \times 10^{-6}}$$

The apparent magnification is 100 times.

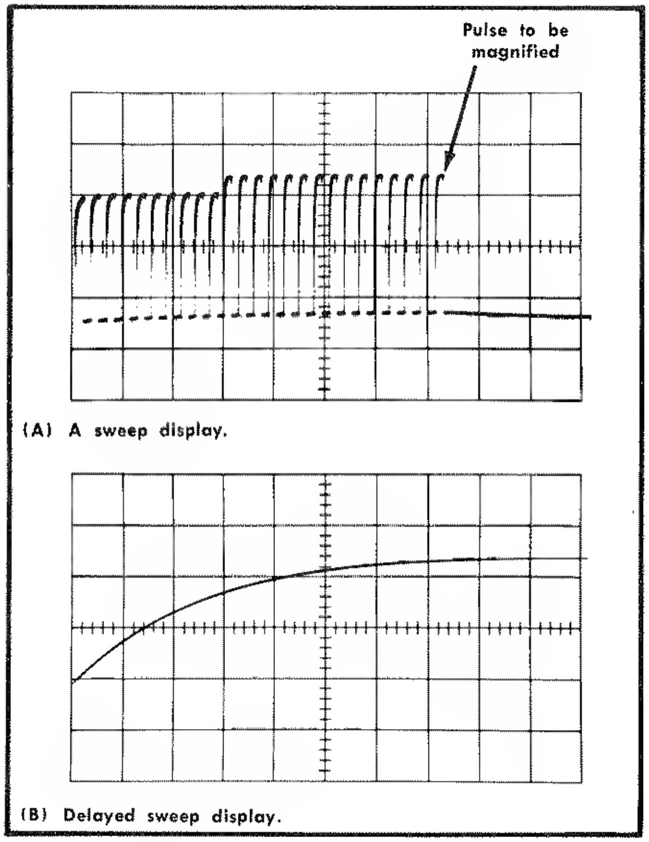
Triggered Delayed Sweep Magnification. The delayed sweep magnification method just described may produce too much jitter at high apparent magnification ranges. The TRIGGERABLE AFTER DELAY TIME position of the B SWEEP MODE switch provides a more stable display since the delayed display is triggered at the same point each time.

1. Set up the display as given in steps 1 through 7 described above.

2. Set the B SWEEP MODE switch to TRIGGERABLE AFTER DELAY TIME.

3. Adjust the B LEVEL control so the intensified portion on the trace is stable. (If an intensified portion cannot be obtained, see step 4.)

4. Inability to intensify the desired portion indicates that the B Triggering controls are incorrectly set or the signal does not meet the triggering requirements. If the condition cannot be remedied with the B Triggering controls or by



(A) A sweep display.

(B) Delayed sweep display.

Fig. 2-21. Using delayed sweep for sweep magnification.

increasing the display amplitude (lower VOLTS/DIV setting), externally trigger B sweep.

5. When the correct portion is intensified, set the HORIZ DISPLAY switch to DELAYED SWEEP (B). Slight readjustment of the B LEVEL control may be necessary for a stable display.

6. Measurement and magnification are as described above.

Displaying Complex Signals Using Delayed Sweep

Complex signals often consist of a number of individual events of differing amplitudes. Since the trigger circuits are sensitive to changes in signal amplitude, a stable display can normally be obtained only when the sweep is triggered by the event(s) having the greatest amplitude. However, this may not produce the desired display of a lower amplitude event which follows the triggering event. The delayed sweep feature provides a means of delaying the start of the B sweep by a selected amount following the event which triggers the A Sweep Generator. Then, the part of the waveform which contains the information of interest can be displayed.

Use the following procedure:

1. Connect the signal to either INPUT connector. Set the MODE switch to display the channel used.

2. Set the VOLTS/DIV switch to produce a display about four divisions in amplitude.

3. Adjust the A Triggering controls for a stable display.

4. Set the A TIME/DIV switch to a sweep rate which displays the complete waveform.

5. Set the HORIZ DISPLAY switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.

6. Position the start of the intensified portion with the DELAY-TIME MULTIPLIER dial to the part of the display to be magnified.

7. Set the B TIME/DIV switch to a setting which intensifies the full portion to be magnified. The start of the intensified trace will remain as positioned above.

8. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B).

9. Time measurements can be made from the display in the conventional manner. Sweep rate is determined by the setting of the B TIME/DIV switch.

Example. Fig. 2-22 shows a complex waveform as displayed on the CRT. The circled portion of the waveform cannot be viewed in any greater detail because the sweep is triggered by the larger amplitude pulses at the start of the display and a faster sweep rate moves this area of the waveform off the viewing area. The second waveform shows the area of interest magnified 10 times using Delayed Sweep. The DELAY-TIME MULTIPLIER dial has been adjusted so the delayed sweep starts just before the area of interest.

Pulse Jitter Measurements

In some applications it is necessary to measure the amount of jitter on the leading edge of a pulse, or jitter between pulses.

Use the following procedure:

1. Connect the signal to either INPUT connector. Set the MODE switch to display the channel used.

2. Set the VOLTS/DIV switch to display about four divisions of the waveform.

3. Set the A TIME/DIV switch to a sweep rate which displays the complete waveform.

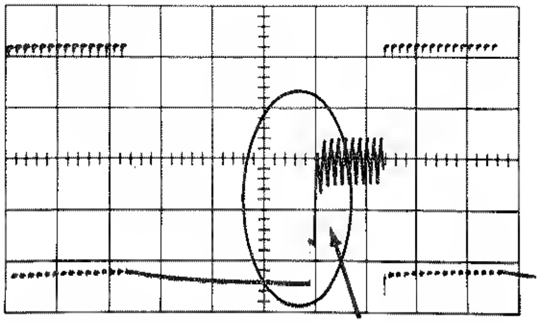
4. Set the A Triggering controls to obtain as stable a display as possible.

5. Set the HORIZ DISPLAY switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.

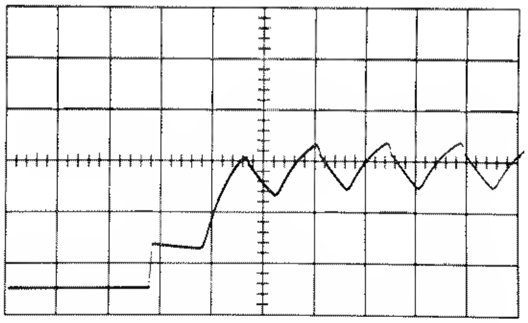
6. Position the start of the intensified portion with the DELAY-TIME MULTIPLIER dial so the pulse to be measured is intensified.

7. Set the B TIME/DIV switch to a setting which intensifies the full portion of the pulse that shows jitter.

8. Set the B SWEEP MODE switch to TRIGGERABLE AFTER DELAY TIME.



(A) This portion of display cannot be viewed adequately because A sweep is triggered on larger amplitude signals at start of display.



(B) Area of interest displayed by delaying B sweep (B STARTS AFTER DELAY TIME mode).

Fig. 2-22. Displaying a complex signal using delayed sweep.

9. Adjust the B LEVEL control so the intensified portion is as stable as possible.

10. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). Slight readjustment of the B LEVEL control may be necessary to produce as stable a display as possible.

11. Pulse jitter is shown by horizontal movement of the pulse (take into account inherent jitter of Delayed Sweep). Measure the amount of horizontal movement. Be sure both VARIABLE controls are set to CAL.

12. Multiply the distance measured in step 11 by the B TIME/DIV switch setting to obtain pulse jitter in time.

Example. Assume that the horizontal movement is 0.5 divisions (see Fig. 2-23), and the B TIME/DIV switch setting is .5 μs.

Using the formula:

$$\text{Pulse Jitter} = \begin{matrix}\text{horizontal}\\ \text{jitter}\\ \text{(divisions)}\end{matrix} \times \begin{matrix}\text{B TIME/DIV}\\ \text{setting}\end{matrix}$$

Substituting the given value:

Pulse Jitter = 0.5 $\times$ 0.5 μs

The pulse jitter is 0.25 microseconds.

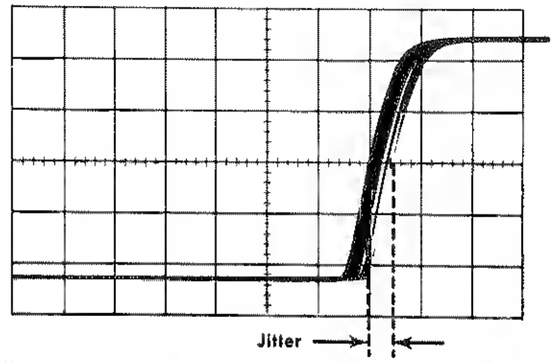


Fig. 2-23. Measuring pulse jitter.

Delayed Trigger Generator

The B GATE output signal can be used to trigger an external device at a selected delay time after the start of A Sweep. The delay time of the B GATE output signal can be selected by the setting of the DELAY-TIME MULTIPLIER dial and A TIME/DIV switch.

A Sweep Triggered Internally. When A sweep is triggered internally to produce a normal display, the delayed trigger may be obtained as follows.

1. Obtain a triggered display in the normal manner.

2. Set the HORIZ DISPLAY switch to A INTEN DURING B.

3. Select the amount of delay from the start of A Sweep with the DELAY-TIME MULTIPLIER dial. Delay time can be calculated in the normal manner.

4. Set the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.

5. Connect the B GATE signal to the external equipment.

6. The duration of the B GATE signal is determined by the setting of the B TIME/DIV switch.

7. The external equipment will be triggered at the start of the intensified portion if it responds to positive-going triggers, or at the end of the intensified portion if it responds to negative-going triggers.

A Sweep Triggered Externally. This mode of operation can be used to produce a delayed trigger with or without a corresponding display. Connect the external trigger signal to the A EXT TRIG INPUT connector and set the A SOURCE switch to EXT. Follow the operation given above to obtain the delayed trigger.

Normal Trigger Generator

Ordinarily, the signal to be displayed also provides the trigger signal for the oscilloscope. In some instances, it may be desirable to reverse this situation and have the oscilloscope trigger the signal source. This can be done by connecting the A GATE signal to the input of the signal source. Set the A LEVEL control fully clockwise, A SWEEP

MODE switch to AUTO TRIG and adjust the A TIME/DIV switch for the desired display. Since the signal source is triggered by a signal that has a fixed time relationship to the sweep, the output of the signal source can be displayed on the CRT as though the Type 453 were triggered in the normal manner (this method does not allow selection of trigger level or coupling).

Multi-Trace Phase Difference Measurements

Phase comparison between two signals of the same frequency can be made using the dual-trace feature of the Type 453. This method of phase difference measurement can be used up to the frequency limit of the vertical system. To make the comparison, use the following procedure.

1. Set the Input Coupling switches to the same position, depending on the type of coupling desired.

2. Set the MODE switch to either CHOP or ALT. In general, CHOP is more suitable for low-frequency signals and the ALT position is more suitable for high-frequency signals. More information on determining the mode is given under Dual-Trace Operation in this section.

3. Set the TRIGGER switch to CH 1 ONLY.

4. Connect the reference signal to the Channel 1 INPUT connector and the comparison signal to the Channel 2 INPUT connector. The reference signal should precede the comparison signal in time. Use coaxial cables or probes which have equal time delay to connect the signals to the INPUT connectors.

5. If the signals are of opposite polarity, pull the INVERT switch out to invert the Channel 2 display. (Signals may be of opposite polarity due to 180° phase difference; if so, take this into account in the final calculation.)

6. Set the CH 1 and CH 2 VOLTS/DIV switches and the VARIABLE VOLTS/DIV controls so the displays are equal and about five divisions in amplitude.

7. Set the triggering controls to obtain a stable display.

8. Set the TIME/DIV switch to a sweep rate which displays about one cycle of the waveform.

9. Move the waveforms to the center of the graticule with the vertical POSITION controls.

10. Turn the A VARIABLE control until one cycle of the reference signal (Channel 1) occupies exactly eight divisions horizontally (see Fig. 2-24). Each division of the graticule represents 45° of the cycle (360° ÷ 8 divisions = 45°/division). The sweep rate can be stated in terms of degrees as 45°/division.

11. Measure the horizontal difference between corresponding points on the waveforms.

12. Multiply the measured distance (in divisions) by 45°/division (sweep rate) to obtain the exact amount of phase difference.

Example. Assume a horizontal difference of 0.6 divisions with a sweep rate of 45°/division as shown in Fig. 2-24.

Using the formula:

$$\text{Phase Difference} = \begin{array}{c}\text{horizontal}\\\text{difference}\\\text{(divisions)}\end{array} \times \begin{array}{c}\text{sweep rate}\\\text{(degrees/div)}\end{array}$$

Substituting the given values:

$$\text{Phase Difference} = 0.6 \times 45°$$

The phase difference is 27°.

High Resolution Phase Measurements

More accurate dual-trace phase measurements can be made by increasing the sweep rate (without changing the A VARIABLE control setting). One of the easiest ways to increase the sweep rate is with the MAG switch. Delayed sweep magnification may also be used. The magnified sweep rate is determined by dividing the sweep rate obtained previously by the amount of sweep magnification.

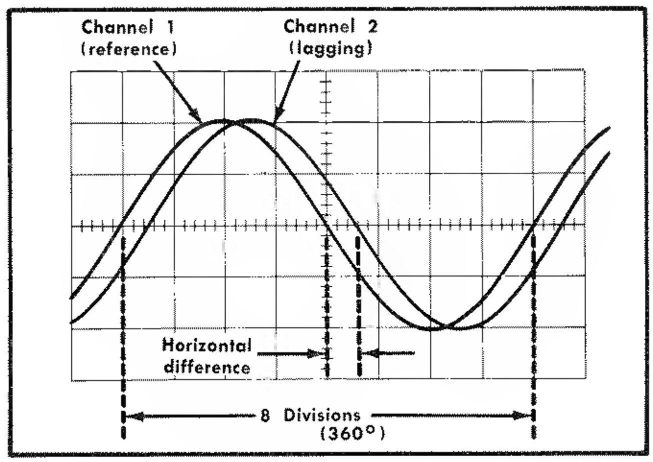


Fig. 2-24. Measuring phase difference.

Example. If the sweep rate were increased 10 times with the magnifier, the magnified sweep rate would be 45°/division ÷ 10 = 4.5°/division. Fig. 2-25 shows the same signals as used in Fig. 2-24 but with the MAG switch set to ×10. With a horizontal difference of six divisions, the phase difference is:

$$\text{Phase Difference} = \begin{array}{c}\text{horizontal}\\\text{difference}\\\text{(divisions)}\end{array} \times \begin{array}{c}\text{magnified}\\\text{sweep rate}\\\text{(degrees/div)}\end{array}$$

Substituting the given values:

$$\text{Phase Difference} = 6 \times 4.5°.$$

The phase difference is 27°.

X-Y Phase Measurements

The X-Y phase measurement method can be used to measure the phase difference between the two signals of the same frequency. This method provides an alternate method of measurement for signal frequencies up to about 100 kilohertz. However, above this frequency the inherent phase

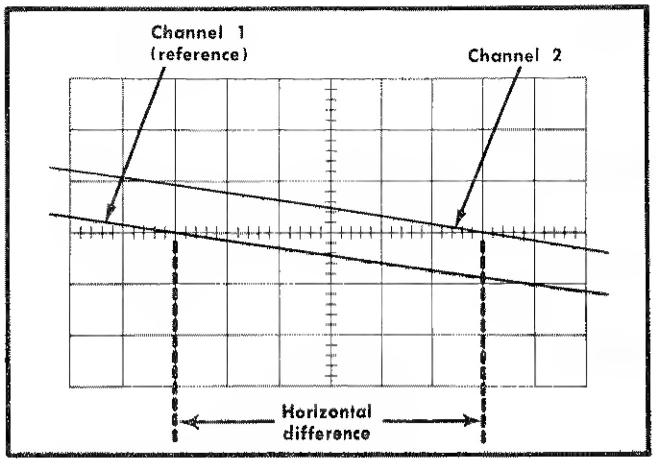


Fig. 2-25. High resolution phase-difference measurement with increased sweep rate.

difference between the vertical and horizontal systems makes accurate phase measurement difficult. In this mode, one of the sine-wave signals provides horizontal deflection (X) while the other signal provides the vertical deflection (Y). The phase angle between the two signals can be determined from the lissajous pattern as follows.

1. Connect one of the sine-wave signals to both the Channel 1 INPUT and the Channel 2 INPUT connectors. (Note: steps 1 through 5 measure inherent phase difference between the X and Y amplifiers to provide a more accurate X-Y phase measurement; not necessary below about 1 kHz).

2. Set the HORIZ DISPLAY switch to EXT HORIZ. Set the TRIGGER switch to CH 1 ONLY and the B SOURCE switch to INT.

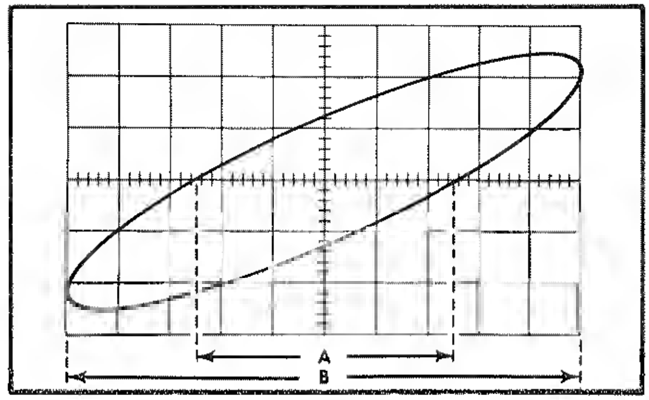


Fig. 2-26. Phase-difference measurement from an X-Y display.

3. Position the display to the center of the screen and adjust the VOLTS/DIV switches to produce a display less than 6 divisions vertically (Y) and less than 10 divisions horizontally (X). The CH 1 VOLTS/DIV switch controls the horizontal deflection (X) and the CH 2 VOLTS/DIV switch controls the vertical deflection (Y).

4. Center the display in relation to the vertical graticule line. Measure the distances A and B as shown in Fig. 2-26. Distance A is the horizontal measurement between the two points where the trace crosses the center horizontal line. Distance B is the maximum horizontal width of the display.

5. Divide A by B to obtain the sine of the phase angle (ϕ) between the two signals. The angle can then be obtained from a trigonometric table. This is the inherent phase shift of the instrument.

6. Connect the Y signal to Channel 2 INPUT connector. Repeat steps 2 through 5 to measure phase angle. If the dis-

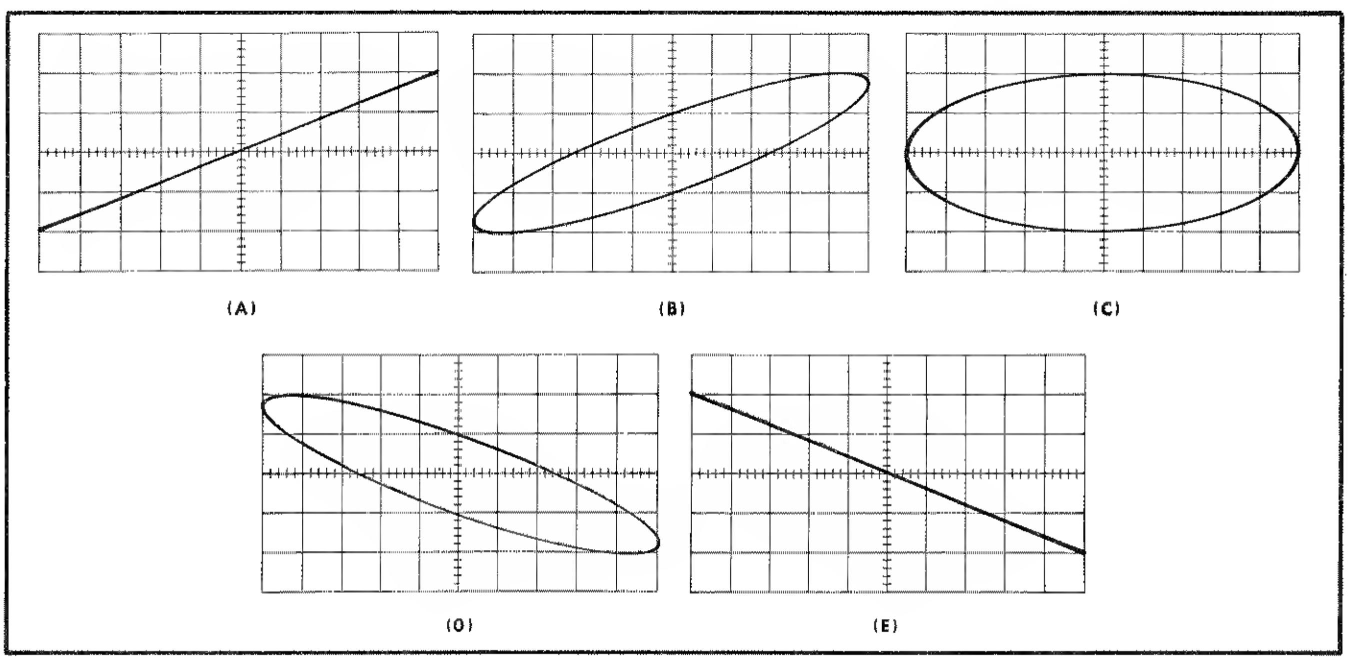


Fig. 2-27. Phase of lissajous display. (A) 0° or 360°, (B) 30° or 330°, (C) 90° or 270°, (D) 150° or 210° and (E) 180°.

play appears as a diagonal straight line, the two signals are either in phase (tilted upper right to lower left) or 180° out of phase (tilted upper left to lower right). If the display is a circle, the signals are 90° out of phase. Fig. 2-27 shows the lissajous displays produced between 0° and 360°. Notice that above 180° phase shift, the resultant display is the same as at some lower angle.

7. Substract the inherent phase shift from the phase angle ϕ to obtain the actual phase difference.

Example. Assume an inherent phase difference of 2° with a display as shown in Fig. 2-26 where A is 5 divisions and B is 10 divisions.

Using the formula:

$$\text{Sine } \phi = \frac{A}{B}$$

Substituting the given values:

$$\text{Sine } \phi = \frac{5}{10} = 0.5$$

From the trigonometric tables:

$$\phi = 30°$$

To adjust for the phase difference between X and Y amplifiers, subract the inherent phase shift.

$$\begin{matrix}\text{Actual}\\ \text{Phase}\\ \text{Angle}\end{matrix} = \phi - \begin{matrix}\text{inherent}\\ \text{phase}\\ \text{shift}\end{matrix}$$

Substituting the given value:

$$\begin{matrix}\text{Actual}\\ \text{Phase}\\ \text{Angle}\end{matrix} = 30° - 2° = 28°$$

Common-Mode Rejection

The ADD feature of the Type 453 can be used to display signals which contain undesirable components. These undesirable components can be eliminated through common-mode rejection. The precautions given under Algebraic Addition should be observed.

1. Connect the signal containing both the desired and undesired information to the Channel 1 INPUT connector.

2. Connect a signal similar to the unwanted portion of the Channel 1 signal to the Channel 2 INPUT connector. For example, in Fig. 2-28 a line-frequency signal is connected to Channel 2 to cancel out the line-frequency component of the Channel 1 signal.

3. Set both Input Coupling switches to DC (AC if DC component of input signal is too large).

4. Set the MODE switch to ALT. Set the VOLTS/DIV switches so the signals are about equal in amplitude.

5. Set the TRIGGER switch to NORM.

6. Set the MODE switch to ADD. Pull the INVERT switch so the common-mode signals are of opposite polarity.

7. Adjust the CH 2 VOLTS/DIV switch and VARIABLE control for maximum cancellation of the common-mode signal.

8. The signal which remains should be only the desired portion of the Channel 1 signal. The undesired signal is cancelled out.

Example. An example of this mode of operation is shown in Fig. 2-28. The signal applied to Channel 1 contains unwanted line-frequency components (Fig. 2-28A). A corresponding line-frequency signal is connected to Channel 2 (Fig. 2-28B). Fig. 2-28C shows the desired portion of the signal as displayed when common-mode rejection is used.

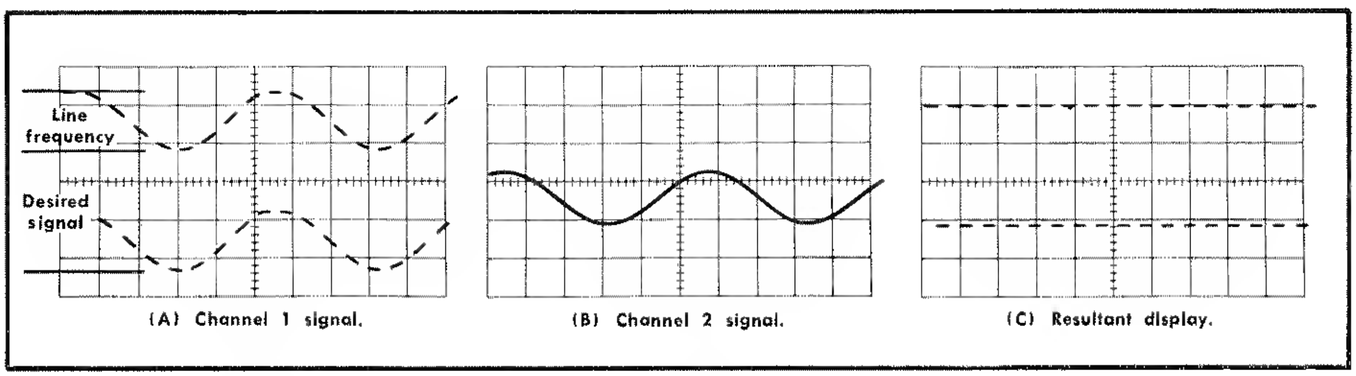


Fig. 2-28. Using the ADD feature for common-mode rejection. (A) Channel 1 signal contains desired information along with line-frequency component, (B) Channel 2 signal contains line-frequency only, (C) CRT display using common-mode rejection.